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The aim of The JOURNAL is to be direct, definite and practical, and to be recognized by progressive electrical men as one of the indispensable aids to effective engineering work.

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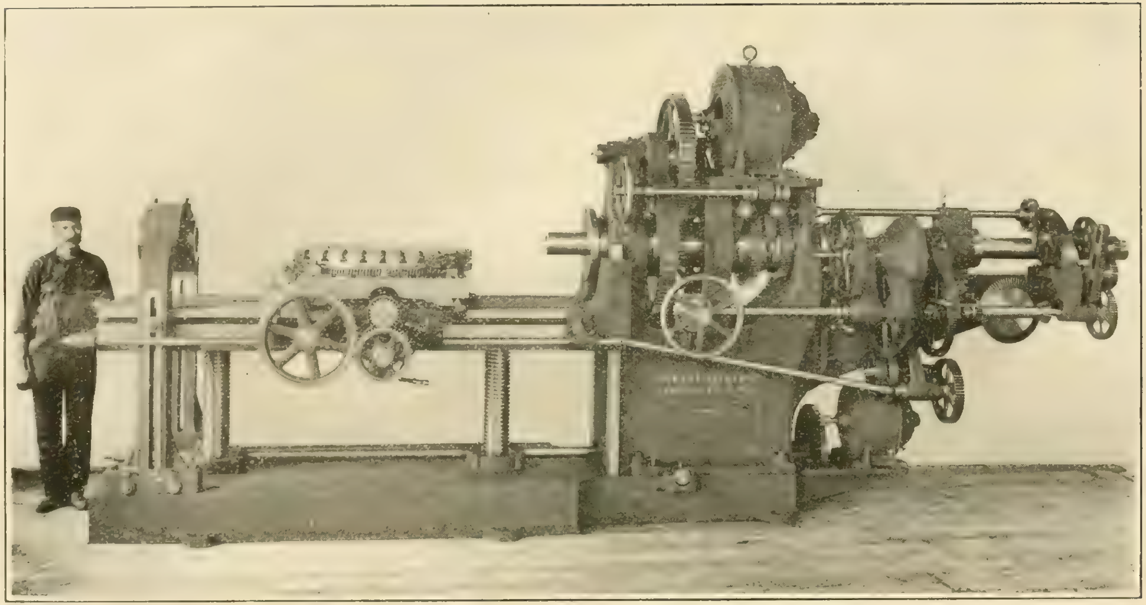


HORIZONTAL BORING AND DRILLING MACHINE DRIVEN BY VARIABLE SPEED DIRECT-CURRENT MOTOR

This machine, built by the Niles, Bement, Pond Co., has a main table nine feet long raised and lowered by a separate motor. The driving spindle is geared directly to a 7 hp Type S motor mounted above the head stock. The motor speed range is from 590 to 1180 r. p. m. With the gears the spindle speed ranges from 99 to 198 r. p. m.

THE

ELECTRIC CLUB JOURNAL

VOL. II JANUARY, 1905 NO. 1

THE INSTALLATION OF A TRANSMISSION PLANT

By A ROAD ENGINEER

The Story of an Early Power House, Some Rotary Converter Kinks and Some Telephone Troubles

IT was late in the fall about eight years ago when I arrived at one of the principal cities of the West. An electric transmission system was in course of construction with a power house newly built at the foothills of the mountains some thirteen miles away and a rotary converter sub-station located in the city

THE POWER HOUSE

itself. I had been detailed to superintend the installation of the apparatus for the transmission system, which was a comparatively new piece of work in those days.

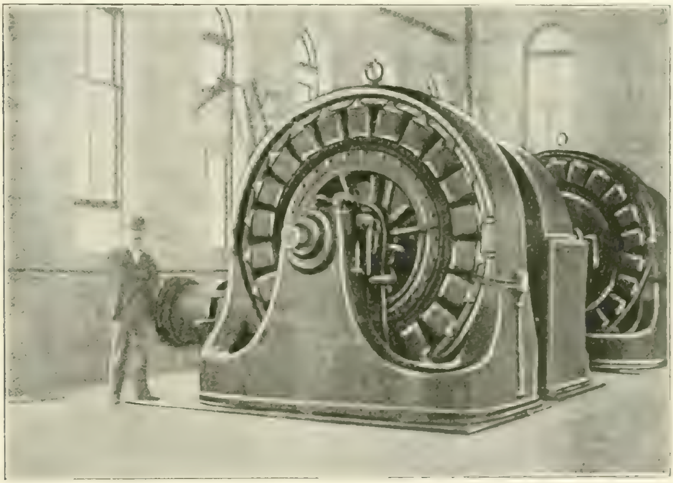
I had been through the old student course at Pittsburg and had gotten some little outside experience, just about enough to make me a little nervous over the outcome of my trip. For no matter how long you have been on the road, each new job is found to be different from the others that you have done. It is often some engineering feature not foreseen in the laying out of the plant, or some operating condition not duly appreciated, or again it happens that the proper facilities for doing the work are not at hand. Indeed enough uncertainties are always present to arouse in one the liveliest interest and no man can foresee just when he will encounter some problem which will test his metal to the uttermost. And I had a premonition that perhaps this job was mine. I already knew that there were some engineering features about this plant, common enough now-a-days, but unusual enough at that time to arouse my liveliest anticipation.

This particular plant was laid out for three 750 kw. generators, but only two were to be installed. They were 60 cycle three-bearing machines arranged to have an impact water wheel mounted on the shaft just where a pulley would be placed if the machine were to be used with a belt drive. Two exciters were furnished, each mounted with a water wheel similarly to the generators. A switchboard, two banks of two phase-three phase transformers for stepping up to 15 000 volts, some high tension bayonet switches and type R lightning arresters completed the power-house equipment. The transmission was thirteen miles and at the receiving end were two 400-kw., 550-volt, 18-pole rotary converters. These converters were the largest that had yet been built for 60 cycles. Indeed few of any size were then in service. The local company had but recently organized and was not yet operating. It had no electrical engineers in its employ and only one employe, a lineman, had ever done any electrical work. The company was to furnish all necessary labor and the manufacturers of the electrical apparatus were to lay out the system and superintend the installation.

The first generator had been shipped some time previous to my arrival and had already been hauled across country from the railroad and was lying at the power house in the mountains, much the worse for its trip. The men who had contracted to do the hauling had not a sufficiently stout wagon to carry the heavy generator weights and the wagon with the armature had broken

down, ruining a considerable portion of the bar winding and end connectors. The first thing to be done, therefore, was to determine what material was needed for repairs and write out an order for the local company to send to the manufacturer. In situations such as this, where the work is done many miles from any kind of a shop, it is quite essential that the road man be prepared to work with his own hands as well as to superintend, and if he have a well-equipped tool chest it facilitates the work very much. I had use for mine when that winding came.

The location for the switchboard and the station wiring had been laid out by the manufacturing company, but on arriving at

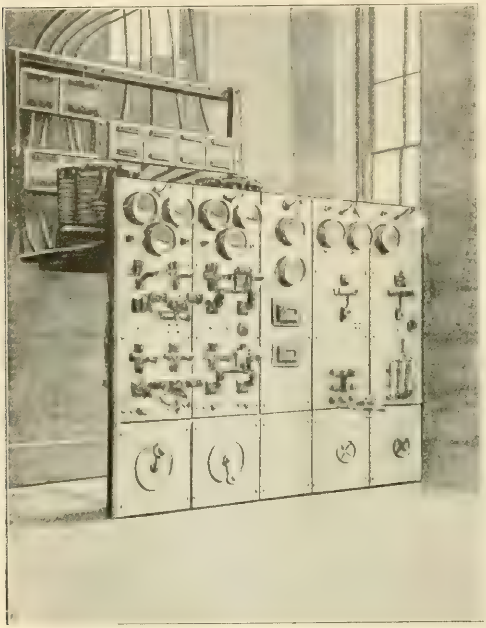


AN INTERIOR VIEW OF THE POWER PLANT, SHOWING THE 750 KW. ALTERNATORS

the plant I learned for the first time that a separate building had been provided by the local company for the raising transformers. It was in such a location that the plans for the switchboard and the station wiring would have to be changed. As usual, no provision had been made in the construction of the power house for putting any wiring into it at all. There was, therefore, no difficulty in changing the proposed location, and I gave instructions to the local company for the building of suitable wiring conduit. This was put in at once.

The transformer house had been built without any provision for high tension switches or lightning arresters. It was only after

considerable planning and a sacrifice of desirable head room that I arranged to have a second floor built in it, which permitted the installation of the apparatus. It was a very cramped position, but it was absolutely needed.

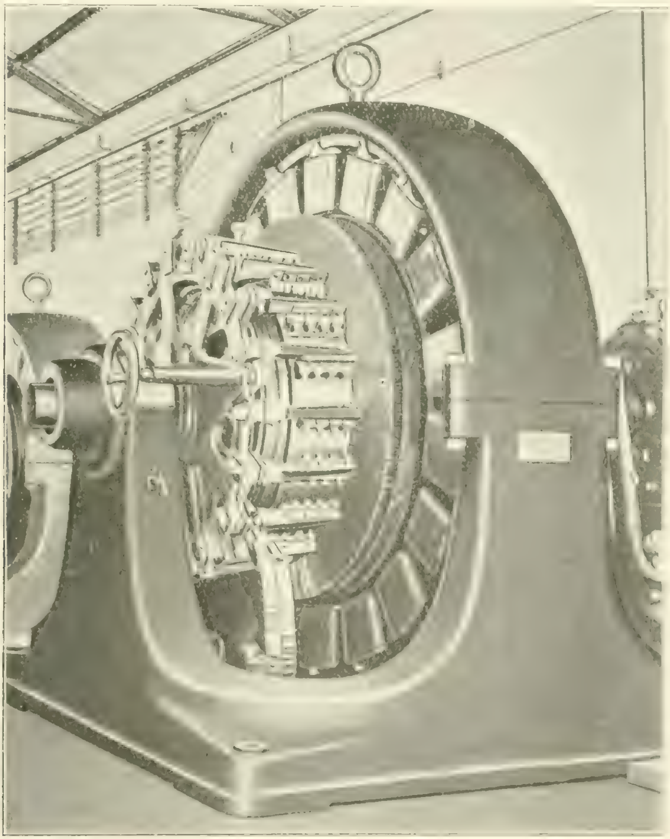


THE SWITCHBOARD

As the engineer was to stay at the plant until it was put in operation it was advisable, in order to save time, to assemble the water wheels and their governing mechanism. While this did not prove to be a difficult task, it was an eye-opener. I got some experience in handling machinery which was new to me and a little out of my line.

The rotary converters, on account of the type, naturally required considerable attention and some experimentation to get into satisfactory service. One of the characteristics of these machines, which occasioned special treatment, was the high commutator speed, which greatly increased the influence of surface roughness upon the commutator. Th combination of high speed and roughness caused the brushes to vibrate, which resulted in rather poor contact between them and the commutator. Of course sparking took place. If the commutator was neglected, the sparking would accentuate the roughness of the commutator and this increased roughness would further aggravate the sparking, so that the sparking would increase at an accelerating rate until the machine would finally buck. This with a uniform load, while all other conditions were good. The cause was not fully understood at the time and it was thought to be chiefly in the setting of the brushes. After a short experience with this machine it was discovered that a smoothness sufficient for slow speed commutation might not be sufficient at a high surface velocity. Although the commutator might feel smooth to the

finger, if the end of a lead pencil was pressed against the back of a brush, a good deal of vibration might be felt. In overcoming this, it was found quite advantageous to support a piece of a grindstone on a properly constructed rest and crowd it against the commutator, while running with the starting motor. This was persisted in until a fresh surface was obtained. After following



400 K. W. ROTARY CONVERTER

this up with very fine sand paper, a surface was gotten which caused no perceptible vibration of the brushes.

A further aid to smooth running was obtained by saturating the brushes with cylinder oil. Two sets of brushes were fitted to each machine and while one set was in operation the other was

immersed in oil. After receiving the above treatment, a machine would commutate perfectly for a very considerable period of time. After this a few hours' work would be required to put it in shape again.

When first put into commission these rotary converters pumped quite badly and no adjustments of their fields would materially improve them in this respect. After some correspondence with the manufacturing company instructions were sent out to me to bore out the fields for a larger air gap and bevel the pole corners. The boring out of the fields was somewhat of a puzzler at first as the machines were too large to be handled by any machine shop in that territory. After a time a boring bar was located that had been used to bore out the cylinder of a medium sized Corliss engine. This bar was mounted in the bearings of a rotary converter after having been reconstructed to bore a sufficiently large diameter. It was belted to the end of the shaft of the other rotary converter which was carrying the railway load. This belt was necessarily small and ran at such a slow speed that it would not transmit power enough to pull the cutting tool through more than a very fine cut, but by taking a large number of cuts the bore was increased to the required amount. While this was being done the manufacturing company sent out two sets of copper dampers to be tried on the pole pieces. One of these sets consisted of sheets of copper bent to the curvature of the pole face and each made to completely cover one pole face. The edges of each sheet were bent up an inch or so all the way around to secure it to the side of the pole piece.

As soon as the above changes had been made on one machine it was brought up to speed by the starting motor and the field was built up. Before, however, the field attained full strength, the machine commenced to make an ominous noise and slowed down. On investigation it was found that the copper facings on the poles had bulged out against the armature and were actually acting as brakes on the armature core. The armature being of the open slot type, its teeth caused the magnetic flux in the air gap to gather in tufts, and as these tufts followed the teeth across the pole faces, they generated such excessive currents in the copper plates that the latter were discolored by heat and pulled out of position by the magnetic action of the induced currents. This difficulty was so great that these dampers could not be used at all. Their action is now well understood and with partially closed slots they make an effective damper. The other set of dampers was made of rectangu-

lar bars of copper surrounding the pole pieces near the tips. Their use and the change in air gap and beveling of the pole corners, resulted in decreasing the pumping to an unobjectionable amount.

Before the above difficulties had been overcome, and, in fact, immediately after the railway load had been transferred from the old steam plant to the rotary converters, the local telephone company and a considerable number of its patrons, whose lines were placed directly above the railway feeders, were much disturbed by a hum in the telephone receivers whenever they were raised from the hooks. In some cases this hum could be heard across a large room, and when the receiver was placed to the ear the noise was very disagreeable. A periodic variation of the sound in synchronism with the pumping of the rotary converters was its most noticeable feature. It did not take the telephone company long to locate the cause of the disturbance and they then proceeded to make things interesting for me, among other things hinting that steps would be taken to prevent the operation of the sub-station. This looked pretty serious as the rotary converters were of a new type and anything tending to bring discredit on them would surely affect future business.

In situations like this it is of advantage to the roadman if in addition to being an engineer he be something of a diplomat. In this instance the roadman was not skilled in this direction, but he did his best to assure the telephone company that his company, to whom the matter had been reported, would do everything in its power to overcome the difficulty, and that a remedy would speedily be found, and then he lay awake at nights trying to think of a remedy but without much success. Various theories had been advanced by different people to explain the difficulty. One was that the armature teeth, which were large and not very numerous per pole, presented varying amounts of iron to the pole faces, thereby causing slight fluctuations in the total magnetic flux, with corresponding pulsations in the e.m.f. and current. The vibration of the brushes was also thought to be a cause of the trouble, the vibration making the contact resistance a variable one with corresponding variations in the current. The smoothing of the commutator and the lubrication of the brushes described above would have reduced the effect of this cause and the increase in the air gap would have reduced any effect caused by the armature teeth. It was never determined how much, if any, of the trouble came from either of these causes, because the complaints from the telephone

company suddenly stopped and no further investigation was made. The telephone company had found that the trouble existed mostly on circuits using a ground or common return and was negligible on an all-metallic circuit properly transposed. They evidently decided that the most satisfactory solution of the problem was the reconstruction of their circuits.

The transmission company had a few telephone troubles of its own. Its circuit from the power house to the sub-station was placed on the same poles as the transmission circuits and it consisted of two insulated wires under one covering. In addition to the braid common to the two, one wire had a braid covering and the other a rubber covering. I never learned just what reasons prevailed in the adoption of this style of construction. It was installed when I arrived and I was called on to operate it for a time. The main difficulty came in getting a sufficient amount of current through the circuit. The talk was very weak at all times. Another and very unique kind of trouble was caused as follows. In the country districts hunters were often out after small birds about the size of meadow larks. These birds frequently lit on the telephone circuit, and when the charge of bird-shot came, one or more of the shot would frequently wedge between the twisted telephone wires and short circuit them. As the wires were seldom cut in two and the insulation was but little frayed these faults were quite difficult for the patrolmen to locate. These short circuits prevented the telephone bells from ringing, but did not prevent the transmission of speech over the circuit, so the operatives at every recurrence of this trouble, would simply go to the phones at pre-arranged times, lift off the receivers, and commence talking. This circuit was soon reconstructed with separated wires and this trouble ended too.

Some months later I was made superintendent of the power company and had ample opportunity to determine the expediency of various things I had done in getting the plant in operation.

THE APPLICATION OF MOTORS TO MACHINE TOOLS

By J. M. BARR

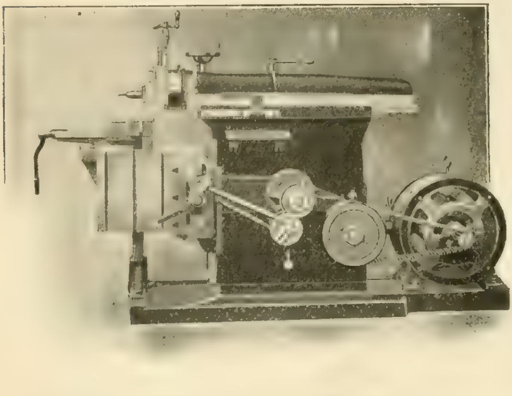
THE conditions under which machine tools operate are so varied that it is impossible to make any general statement covering all of the possible operating conditions. But some of the governing conditions are always important as, for instance, the character of the work machined, the kind of material cut, the shape of the cutting tool, the quality of the tool steel, the method of treating the tool steel, the stiffness of the machine tool proper, the strength of the gears, etc. All of these should be taken into account in intelligently fitting a motor to any particular machine tool.

Broadly speaking, machine tools may be divided into two classes—first, those with a direct rotary motion, either of work or cutter; and, second, those with a reciprocating motion, either of work or cutter. Under the first classification come lathes, boring mills, milling machines, drill presses, etc. The second class includes planers, shapers, slotters and machines of a similar character.

The following formulae are based on standard American practice and will be found useful, particularly for estimating work. Under unusual conditions of operation, the horsepower given by the formulae may be greatly exceeded, but if the machine tool is to be run under abnormal conditions, it will be necessary to analyze the power requirements at further length rather than to rely upon empirical formulae.

It is to be noted here that whatever the class of machine tool, the variable speed motor generally offers decided advantages in the way of rapid and economical production. With the old method of speed variation, by means of cone pulleys or nests of gears, only coarse increments in speed are obtainable. This invariably means that tools cannot be worked up to their limit of productive capacity. With the new high speed steels requiring a greater pulling power in the belts and an increased strength in the gears, reasonably fine increments in speed, by mechanical methods alone, are almost impossible, owing either to the increased length of the cone pulley or the necessarily abnormal size of the change gears.

For this reason the variable speed motor may in some cases actually decrease the cost of the machine tool by eliminating extremely bulky and expensive mechanical speed changing devices.



24-INCH BACK GEARED SHAPER DRIVEN BY A VARIABLE SPEED DIRECT-CURRENT MOTOR. CINCINNATI SHAPER COMPANY

The following horsepowers which are mentioned in connection with machine tools of different sizes are based on a cutting speed of approximately 20 feet per minute, the assumption being that water hardened steels are used, and also that the work is done upon a normal machine tool, as distinguished from the modern high speed machinery. Where the cutting speed is more than 20 feet per minute, the horsepower required should be increased approximately in proportion to the increase in speed.

The approved practice in the matter of cutting speeds is to make the ratio between the various speeds increase in geometrical progression, and as it is somewhat laborious to calculate in each case what the speeds will be on the controller notches, the curve shown in Fig. 1 has been prepared. This curve has been laid out on the basis of standard practice, in which the number of notches on the single voltage is eight, while on the double voltage 15 notches are used.

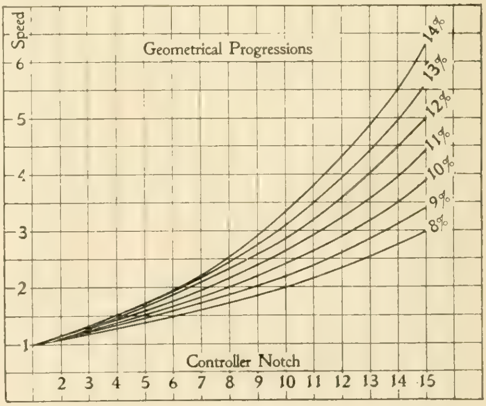


FIG. 1—RATIO BETWEEN SPEEDS AT CONTROLLER POINTS

The vertical represents the total increments in speed, the horizontal, the controller notches; while the curved lines each represent a certain percentage of the increase between the notches. For ex-

ample, on the 15th notch of the controller having 14 per cent. increments, the speed will be 6.25 times the initial speed.

In general, the handle of the controller used in connection with variable speed motors should be located convenient to the operator, as, for example, in the case of a lathe, good practice places the handle on the tool carriage so the changes in speed may be made without the necessity of the operator leaving his position at the tool carriage. Connection between the controller handle and the controller proper should be made as rigid as possible, in order that the notches on the dial of the controller may correspond as nearly as possible to definite running positions on the controller.

POWER FOR MACHINES HAVING ROTARY MOTION

In general, the motors to be used for lathes, boring mills, drill presses, etc., should be shunt wound, variable speed motors, with good inherent speed regulation.

1. *Lathes*—Engine lathes using one cutting tool of water-hardened steel at about 20 feet per minute:

hp=.15 S—1 hp.

Heavy engine lathes, such as forge lathes:

hp=.234 S—2 hp.

In all cases, S=swing of lathe in inches.

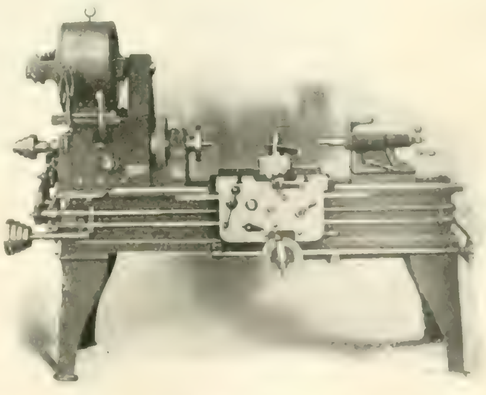
2. *Boring Mills*—For the operation of standard boring mills using one cutting tool of water-hardened steel at approximately 20 feet per minute, the following formula will be found to represent good practice for heavy work:

hp=.25 S—4 hp.

Where S=swing of mill in inches.

This formula applies more particularly to mills having a 30-inch swing and above. For smaller boring mills the formula as given in connection with heavy engine lathes will be approximately correct.

3. *Milling Machines*—For normal milling machines using water-



A VARIABLE SPEED DIRECT CURRENT MOTOR DRIVEN LATHE OF THE [illegible] TOOL COMPANY

hardened steel cutters running at about 20 feet per minute, the following formula will be found useful:

hp=.3 W

Where W=distance between housings in inches.

4. *Drill Presses*—For normal drill presses using water-hardened steel drills, running at a peripheral cutting speed of approximately 20 feet per minute:

hp=.06 S

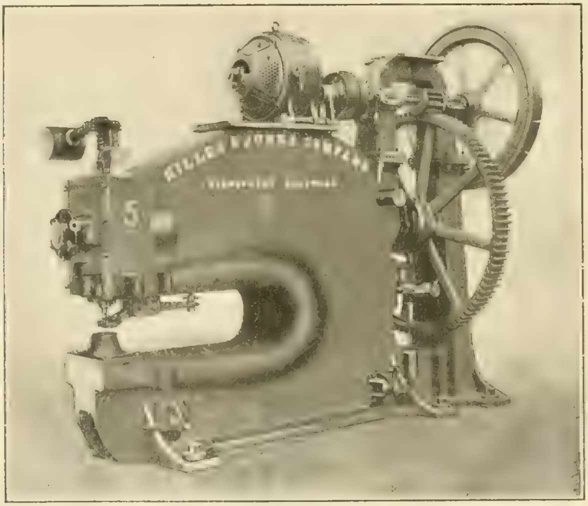
For heavy radial drill presses:

hp=0.1 S

Where S=capacity of drill in inches.

MACHINES HAVING RECIPROCATING MOTION

Machines of this character are from their nature less productive than machines having a purely rotary motion. For this reason



VARIABLE SPEED DIRECT-CURRENT MOTOR DRIVING HILLES & JONES DEEP THROAT PUNCH

it is especially important that machines having a reciprocating motion be run to the limit of their capacity.

This, of course, means a variable speed motor, similar to the motor described in connection with rotary motion machines, except that in the case of machines having a reciprocating motion the compound wound motor should invariably be used. The compound wound motor is useful in that at the instant of reversal, when the torque required of the motor increases very considerably above the

normal, the compound winding assists materially in holding the in-rush of current within reasonable limits; and this may be further improved by the use of a fly-wheel.

The following figures show average practice for the operation of some of the typical reciprocating machines.

1. *Slotters*—Normal crank slotters, using water-hardened steels at cutting speeds of from 15 to 20 feet per minute:

Stroke	Horsepower
10 inches	5
18 inches	7
30 inches	10

2. *Shapers*—Shapers using water-hardened tool steels at cutting speed of from 15 to 20 feet per minute:

Stroke	Horsepower
16 inches	3
18 inches	$3\frac{1}{2}$
24 inches	5
30 inches	$6\frac{1}{2}$

3. *Planers*—For normal planers using water-hardened steel at cutting speeds of from 15 to 20 feet per minute:

$hp = 3\ W$

For heavy forge planers:

$hp = 4.92\ W$

Where W=width between housings in feet.

The above formulae are for planers having a ratio of cutting to return speeds of approximately 1 to 3, and cover planers with two tools in operation. If more than two tools are used, or if the ratio between the forward and return speeds is more than 1 to 3, the horsepower given by above formula should be increased.

In connection with the above, it should be noted that where the machine tools in general are run under abnormal conditions, or in the case of abnormal machines, the only rational method of obtaining the horsepower is to make a careful study of the conditions under which the machine operates, to develop by means of suitable formulae the horsepower required at the cut, adding to this the horsepower required to drive the machine tool in question when running light. This latter method of analysis is based upon a large number of tests and requires in addition to the formulae representing the horsepower at the cut, considerable experience in order that formulae may be properly applied.

THE OPPORTUNITIES IN THE ELECTRICAL BUSINESS*

By GEORGE A. DAMON, M. W. S. E.

THE electrical business is a complicated one, and is constantly undergoing changes. By the time a method or a system becomes standard enough to be looked upon as a precedent, a tendency develops in some entirely new direction. The men who succeed in electrical work must therefore be quick to grasp the lessons of the past, must be ready to appreciate the limitations of the present, and above all, should be alert to seize the opportunities for improvement.

The leaders in the various branches of the industry during the first developments, when electrical work was an art and not a science, were graduates from the well-known university of *Hard Knocks*. The men of the second generation of workers who are now doing things are largely the product of a semi-scientific training in schools of technology, supplemented by experience of a practical nature picked up in a more or less haphazard way. A few years more will see the development of a third and better prepared generation of electrical experts, and it is safe to say that they will be the result of a combination of a practical training thoroughly mixed with a theoretical education. As it must be expected that the next generation will be superior to the present one, will it not be well to stop for an instant in the strenuous rush for results and make a few suggestions which may be of assistance to our successors in planning their life work?

Work harder—dig deeper—put in a better cement foundation, are the keynotes of the suggestions which our older brothers give to us as the result of their experience, and the ambitious young man will be quick to recognize the value of their advice. But what is wanted most is some definite information as to how to spend the time devoted to preparation in the most efficient manner, and how to get the benefit of a combined training in theory and practice in the most effective way.

Knowing that the leading electrical men of Chicago would afford a valuable field for studying results and would welcome an opportunity to help furnish a solution for these problems, a letter of inquiry was sent to one hundred men in Chicago engaged in the

*Abstract by the author of a paper read before the Western Society of Engineers, March 18, 1904.

various branches of the electrical industry. An opportunity was given at the same time for the expression of opinion on various questions pertinent to the general subject. The response to the circular letter was hearty and spontaneous, and we are under obligations to one hundred of our friends who have so kindly consented to become living examples, and willing to be analyzed for the good of the cause.

Young men control the business. The inquiry was, therefore, confined to men between the ages of 27 and 45, upon the theory that the older men are the product of a set of conditions which have passed away, while the younger men are, as a rule, still engaged in a period of preparation. The average age is thirty-three and one-half years.

The hundred men may be divided into groups as follows:

	No. of Men.	Average Age.	Average Income.
Salesmen	7	33	$2,400
Sales managers	11	36	3,400
Business men	10	36	4,800
Sales engineers	8	35	2,350
Electrical engineers	16	33	2,800
Constructing engineers	6	33	2,850
Electrical experts	8	33	3,200
Operating engineers	3	32	2,250
Operating managers and superintendents	10	34	3,550
Professors and editors	8	34	2,500
Patent attorneys	4	32	4,000
Consulting engineers	9	40	6,400

Total number of men, 100. General averages: Age, $33\frac{1}{2}$ years; income, $3,440.

Classified in reference to incomes, the record is as follows:

	Men
Income over $10,000 per year	5
Income between $5,000 and $10,000	9
Income between $2,400 and $5,000	66
Income below $2,400	20
Total	100

It must be remembered, however, that the dollar is not the most desirable standard by which to measure men individually, but looked upon as a class, a study of the averages furnished by this inquiry is interesting and may be instructive.

Salesmen who have technical ability or who possess engineering information, as a rule, get better salaries than those who do not.

Add initiative and executive ability to the salesman and he becomes a sales manager with a still greater reward.

Enterprise and energy put the man in possession of his own business, or often result in a partnership arrangement. A technical man without commercial instinct is only fairly well paid. Ability to develop new methods or apparatus puts him in the expert class where the rewards are greater and in proportion to his ability.

Routine work, such as operating, is the least remunerative of all work. Operating managers and superintendents, however, are well paid.

The phenomenal development along all electrical lines, makes the profession of patent attorney a paying one for those who are qualified for that kind of work.

The field of consulting electrical engineering looks attractive, but it will be noted that the average age is greater in this branch than in the others, which means that the successful consulting engineer brings to his work years of experiencee, and that it is, therefore, not a branch to be adopted at once by the young man.

Forty per cent. of the men in the list are employed by what might be termed the large companies, such as the Western Electric, Chicago Edison, Chicago Telephone companies, etc.

Thirty-five per cent. of the men either control the business in which they are engaged or own a partnership interest.

Twenty-five per cent. of the men are not college graduates.

Twenty per cent. of this hundred successful men never had any college education whatever.

The average age of the twenty men who are succeeding without a college education is 36 years, and their success measured by a monetary standard shows an income of $3,670 per year.

The average age of 16 graduates of Cornell is also 36 years, and their success, measured by the same questionable standard, is $4,940, which shows a balance of $1,270 per year in favor of the man with a college education.

It will be noted, however, that the twenty men without the education are financially slightly in advance of the general average of $3,440 per year. This is explained by the fact that in their number are included several men who are prospering as a result of their business enterprise.

There are few non-technical men engaged in the strictly technical end of the business who reach the average income.

There seem to be more openings for the man without a college training in the telephone field than in any other.

Out of the hundred men selected, only fifty-six per cent. belong to the American Institute of Electrical Engineers.

Eighty per cent. are inclined to think that a college education is essential to the highest success.

Seventy per cent. are in favor of the technical graduate taking a shop course in a large manufacturing company, but many wished to limit this course to one year.

Seventy per cent. are in favor of requiring a year's practical work of the student before graduation.

The replies to some of the questions are exceedingly interesting, and a few of these in answer to the question, "In the light of your present experience, and under existing conditions, what course would you follow if you had it all to do over again?" are given below:

"Same as I have, only dig harder when at college, and later also."

"I would get my technical course early in some school where I could be in contact with and imbibe as much of a literary training as possible."

"College, practical work in summer, if possible, and if not, apprentice course afterwards. At least two summers in some commercial business, learning office methods and also how to approach men in business life."

"Get all the general education and practical experience practicable before taking up the technical course; then make the most of that."

"Just as I did, i. e., a few years' practical work interspersed with the college course, followed by a term in the testing department of one of the large electrical concerns."

"Mechanical English, with electrical courses taken as specials."

"I would do just the same as I did before, namely, get a good school education, then serve an apprenticeship in some suitable shop, acquiring theory in spare moments, and then go to college."

"Take the college course, and get all the practical experience during vacation I possibly could."

"Work harder."

"Would enter testing department of large company immediately after graduation from college."

"Take a M. E. course with as much elective work in electrical and civil engineering as possible. Spend vacations with a surveying party and in a shop. Extend course to five or six years if necessary to get the amount of work stated."

"Think I would do about the same, excepting I would spend at least two years in a machine shop and on outside work—repairing and the like."

"Would not leave college until I had a very thorough training in mathematics. Would spend some time in operating work and then go into the draughting room and stay at least two years. Then into either the operating or business side."

"I would take a course in mechanical engineering and take a post-graduate course, or else, during the time of mechanical engineering studies, take up electrical work, and then enter some shops and get practical experience, after which spend at least two years drafting. A man may, in all probability, at the end of that time be of some value to himself and others."

"I would put in a couple of years with one of the large companies, where I could get the largest amount of experience, regardless of remuneration."

"I would use every effort to get stock in the concern with which I saw fit to identify myself after completing my university course."

"Get a college education interspersed with at least one year of practical work."

"Take a good common and high school course, then several years at practical work, and enter a technical school knowing what points I wanted to give special attention."

"Spend all the money I could 'scrape' together for a technical course in the best college I could find."

"Save more, study more, work more—talk less."

"First, college education; second, go into the shop of a reliable manufacturing company."

"I would secure technical training."

"I would, if I had made up my mind to pursue an electrical course, take a technical education, if possible, in connection with a business one."

"Dig deeper and commence earlier."

"I would work at practical work for two or three years and then go to college. Lots of time in college is wasted for want of practical understanding."

As a result of personal observation, tempered somewhat by the opinions of the electrical men, with whom these questions have been discussed, the writer presents the following conclusions:

A COLLEGE EDUCATION

A young man wishing to succeed in any branch of electrical industries makes a serious mistake if he fails to use every effort to obtain a technical education. A college course is becoming easier to obtain and it is already recognized as a general requirement for advancement. A young man of high aspirations who is so situated that he cannot secure a university course, might better, nine times out of ten, take up some branch of work which is less intricate than the electrical art. Thomas Edison, the dean of the profession, is not a college man, but a gold medal bearing his name is to be given hereafter each year to the college graduate presenting the best thesis, and this incident is the best evidence of the present tendency toward technical education. Nearly every man who is now making his way in the electrical business without a college training, if asked what he would do if he had his life to live over, will say, "I would secure a technical course in the best college I could find."

PRACTICAL EXPERIENCE

Practical experience is as essential as theoretical training. Students have paid too little attention to getting into thorough contact with the way things are actually done. This is the result of the general practice of allowing the young man to shift for himself. "I can't get a job without experience," he says, "and I can't get experience without a job"; and then, more or less discouraged at the outlook, he takes the first opening presenting itself, which may or may not be the kind of work for which he is fitted. What is needed is a general clearing-house of information, a closer union between the ambitious student and the successful men who have been pioneers in the work. The electrical business has now progressed far enough that the actual experience essential for the highest success along any one of its various lines can be generally indicated by experts familiar with the ground to be covered. It is time, therefore, to abandon a thoughtless and perhaps selfish attitude toward the beginner and make some organized effort to map out the territory which he must travel with guide posts and signs marked, "This Way to the Front."

An association of thoroughly successful men should exercise some supervision over the preparation of the coming generation. If it is true that the art is suffering to-day from a lack of trained

men ready to take up and solve the problems which are all about us, what must we expect of the morrow with its widening opportunities? The student branches of the American Institute of Electrical Engineers, and the recently formed Edison Medal Association, are moves in the right direction, but only a beginning toward realizing the best technical course. A college training is less than half of an education. What constitutes the other half is a big problem waiting for a comprehensive answer.

SHOP COURSES

The policy of the large companies in offering apprentice courses and opportunities for experience in their testing departments is to be commended. However, as carried on in some cases, it is to be criticized. A representative of a large manufacturing company visits a technical school, offering to give positions to all the members of the senior class; the professor is highly complimented at this remarkable courtesy, and advises his students to accept. The *shop* course usually covers a period of two years. The hours are long and the pay is small. The experience gained by the student may or may not justify the sacrifice. It depends largely on the man. In the meantime the large company has a good opportunity to select the material which it requires for its own use, and perhaps twenty-five per cent. of the shop graduates have a reason to feel enthusiastic over the system; the others pass through days and nights of discouragement, and may leave the shop with a sense of failure, which is sure to have an influence on their future.

All men are not built alike. Then why grind them through the same mill? Should not some selections of materials be made before the mills are started, a sorting over made earlier in the process? Perhaps the mills themselves could be made a little more efficient. It does seem possible that a commission made up of the broadest men in the profession, some from the large companies and some from outside practice, could do much toward improving the facilities and present systems for *getting experience*.

THE STUDENT'S PART

The trouble with a great many young men is that they don't *find* themselves early enough in life. They fail to realize the possibilities and are not prepared to grasp their opportunities. Ambition, aptitude, preparation and hard work are the stepping stones to successful attainment. Let the ambition to excel be deeply seated and directed along the lines of natural endowment; let the purpose

be firm, and as day follows night, the preparation will be thorough and the man will be known by his works. "If I had it to do over again I would pick out some definite line of work suited to my talents and work like fury," is the advice of many successful and even unsuccessful men.

The purpose of this paper is to encourage the efforts of the students in our colleges by presenting the results which have been attained by their predecessors; to crystalize the sentiment in favor of a scientific combination of theory and practice, and finally, to give an opportunity to the men on the fighting line to point the way to their successors, who must come to the front prepared in every way, if they intend to take some part in the phenomenal developments which are to be expected.

In order to direct the consideration along definite channels, the following is offered as a suggestion to a young man seriously considering engaging in the electrical business:

A SPECIFICATION FOR SUCCESS

In general, the purport and intent of this specification is to cover the labor and material required to produce, in complete working order, a man prepared to attain his own ideal of success in that branch of electrical work which he may elect.

It is to be understood that the omission of the mention of small details in this description does not obviate the necessity of their being furnished. What is wanted is a thoroughly trained, well-seasoned, broad-minded man, complete with an individual character, a strong intellect and a sincere purpose.

Plans—He will form his ambition early in life.

He will take a natural interest in the history of men of eminence in his chosen work, and their achievements will inspire him with a desire to accomplish great things.

He will develop his imagination and constantly broaden his conception of his own possibilities.

He will seek to learn what the world wants and then will endeavor to train his natural abilities so as to supply that want.

Foundations—He will, as a boy, develop a knack of doing things, either as a mechanic, as a draftsman, or in some boyish business enterprise, and a combination of any two or all three proclivities is desirable.

He must early learn the advantage of doing some one thing well, but he should not allow praise for his proficiency to encourage him to neglect study along the lines he does not naturally fancy.

He will prepare for college and during this period of preparation he will get enough experience in practical work to demonstrate that he has made a wise choice for his life work.

He will not let the attractions of practical work interfere with his intentions to secure the best theoretical and technical training the country affords.

Dimensions—He will endeavor early to earn money by doing useful work, and will seek employment outside of his study hours. Everything he attempts he will complete to the best of his knowledge and ability.

He will put himself on a self-supporting basis as soon as possible, and will earn his own way through college. If he receives financial assistance, he will treat it as borrowed money, to be returned, and he will keep the debt within reasonable limits.

He will determine for himself whether he intends to realize on his possibilities quickly or whether he will lay a broader foundation for a slower but higher development.

Capacity—Even if the young man possesses only ordinary talents, his capacity for hard, conscientious, intelligent, well-directed work will attract attention and win advancement.

When the occasion demands, he will be able to stand a long run on overload or respond to excessive demands for short-periods without permanent injury.

He will be able to direct others and will not depend entirely upon his unaided efforts for results.

Operation—He will work quietly, and will be turning in the right direction every minute in a simple, direct and accurate way. He will join that great army of workers who are actually doing things, rather than that smaller class of men who occupy most of their time telling what they are going to do.

Parallel Operation—As a student he will enroll as a member of the Student Branch of the American Institute of Electrical Engineers and take a lively interest in the Institute papers, and discussions. In practice, he will advance to associate membership and will look forward to the day when he has added sufficient to the art to be considered worthy of full membership.

He will make friends among his superiors, who will respect his ambitions and will be glad to assist him in realizing his ideals.

He will study men and learn how to deal with them.

Work to be Done by Others—Parents should study their children and encourage them to develop their natural tendencies.

Teachers should get hold of their students personally and as far as possible treat each case individually.

More occasions should be made for successful men to meet students and give them the benefit of their advice and experience.

The students should not be isolated in a little world of their own, but should be brought in contact with an atmosphere of actual affairs.

Above all, some method must be devised to guide each young man to and through the course of practical experience best adapted to his individual qualifications and purpose in life.

Shop Tests—If he enters the shop or testing department of a manufacturing company, he will make a bargain which will result in his getting an all-around experience in exchange for his services, and, while in the shop, will keep on the move in every sense of the word.

He will seek to make himself thoroughly practical in all his ideas and methods of work.

Finish—He will include in his preparations considerable literary work and will seek after a general culture. He will study at least one foreign language.

He will regard his college work as only the beginning of his education and will be a student always.

He will seek practice in the art of expressing himself, and will occasionally write a paper on some technical subject.

He will become interested in some social, educational or reform movement, and will avoid becoming a recluse interested only in his own work.

Fittings—He will find it necessary to possess accurate knowledge of nearly every branch of science, including physics, chemistry, mathematics, mechanics, pneumatics, hydraulics, mining, metallurgy, and civil engineering.

He must know something about accounts and a great deal about business and commercial law.

He will find that the electrical business is so broad in its scope that a natural aptitude in any direction can be made of use.

Completion—He will make every sacrifice to get a thorough preparation and a broad experience up to the age of 28 or 30 years.

He will accomplish much between the age of 30 and 45, at the end of which time he will be well settled in his business or profession.

DAMPERS FOR SYNCHRONOUS MACHINES

By E. L. WILDER

HUNTING in a synchronous machine is a periodical variation in the speed above and below synchronous speed. This may occur either between alternators which are working in parallel supplying current to common feeders, or it may occur between an alternator generating power and a rotary converter or synchronous motor to which its power is supplied.

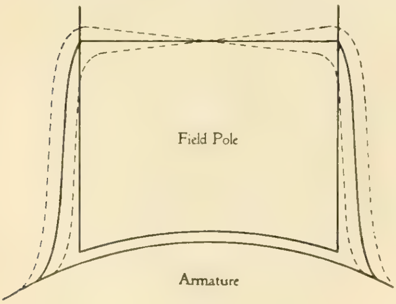


FIG. 1

Consider the case of two alternators operating in parallel: When they are in synchronism the electromotive forces in the circuit including their two armatures are in direct phase opposition, and there will be no interchange of current, if the two machines have similar wave forms and the excitation is the same. If, however, one machine lags, a resultant electro-motive force will be developed which will cause a current to flow. This current takes power from the machine which is leading, and supplies it to the machine which is lagging, the obvious effect of which is to raise the speed of the lagging machine and to lower the speed of the leading machine. If on account of the inertia of the moving parts the machine which was lagging now forges ahead, the conditions are reversed, and thus begins an oscillation of current and speed which under certain conditions may become troublesome.

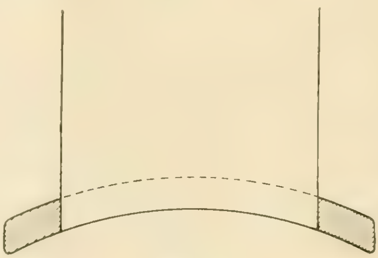
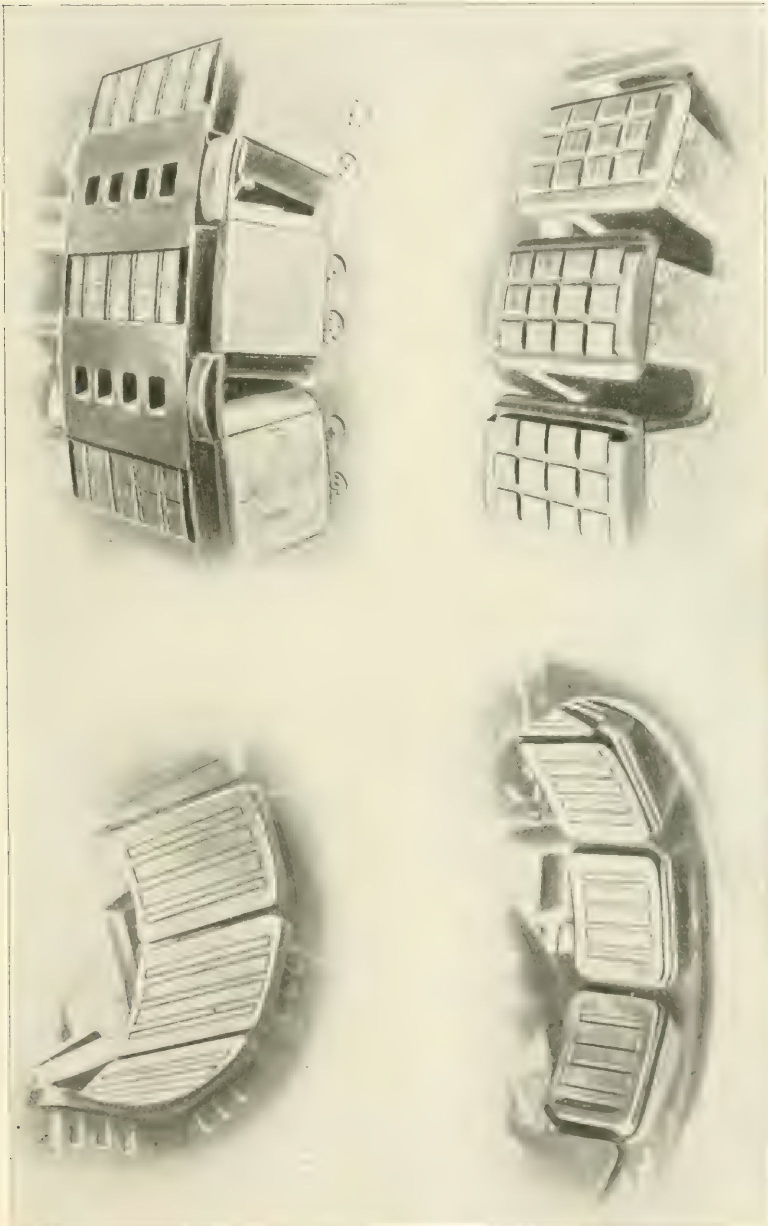


FIG. 2

These currents which flow between two machines, thereby holding their average speeds to the same value, are called corrective currents. It is these which react upon the field flux and cause it to shift first in one direction and then in the other. Thus, in Fig. 1,



THE TWO UPPER VIEWS SHOW ACTUAL DAMPERS FITTED TO ROTATING FIELD ALTERNATORS. THE TWO LOWER VIEWS SHOW DAMPERS FITTED TO THE POLES OF ROTARY CONVERTER FIELDS

let the full line represent the normal field-flux form. The dotted lines will represent roughly the limiting forms between which the flux will vary as the machine oscillates between a lagging and a leading position. This oscillation in speed may be restricted by the action of copper dampers placed upon the poles. For the sake of simplicity, disregard the presence of the flux set up by the field and assume the armature to be in rotation. When the machine is in synchronism, the flux set up by the armature rotates with respect to the armature at the same speed at which the armature is rotating, but in the opposite direction, so that the flux is stationary with reference to the frame of the machine.

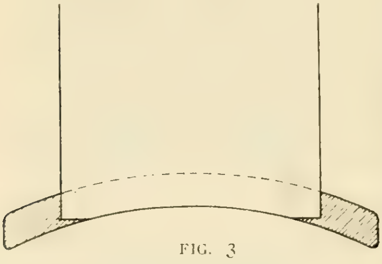


FIG. 3

The armature may then be considered as a stationary electro-magnet, excited by direct-current, whose magnetic circuit is completed through the frame of the machine. When the condition of hunting prevails the armature may be considered as an electro-magnet which vibrates from its normal position, changing its strength as it swings back and forth, and becoming strongest when it is farthest removed from its normal position. If now we regard the field of the motor as excited, the resultant field due to field flux and armature flux will still vary since the field flux proper is constant for a given constant field current.

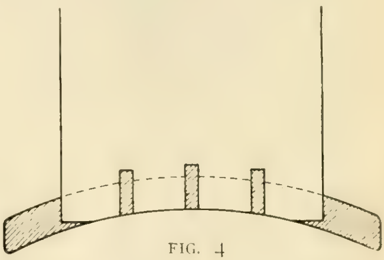


FIG. 4

If a copper sheet or copper grid is placed so that the flux will cut across it, the pumping or vibration will be dampened by the eddy currents set up therein according to Lenz's law. This is the function performed by the copper dampers placed on the poles of alternating current machines which are intended for parallel operation.

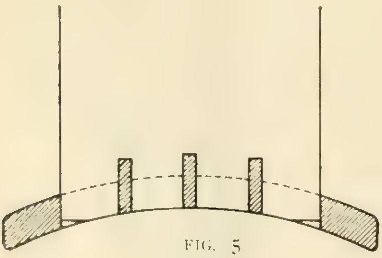


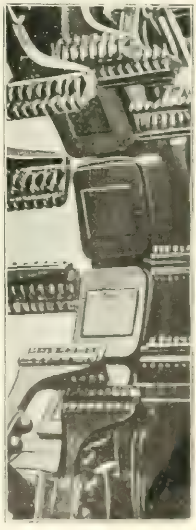
FIG. 5

Hunting is very much like the swinging of a pendulum. If

there is little friction a small force will keep up the vibration. The addition of the dampers is analogous to immersing the bob of the pendulum in a heavy oil which resists the motion of the pendulum.

FIG. 6

One of the earliest forms of dampers is illustrated in Fig. 2. It consisted merely of a heavy copper ring surrounding the pole tip. Its effectiveness as a damper is rather low. A later form is shown in Fig. 3, the copper here being extended under the pole tip in the form of a lip. This modification greatly increased the damping effect. A still later form is illustrated in Fig. 4, the damper being in the shape of a grid which is set into slots in the pole face. Fig. 5 is a modification of this form. Fig. 6 shows a very effective damper, which consists simply of a heavy copper sheet fastened to the face of the pole. This form can be used only with partially closed armature slots on account of the eddy currents which would otherwise be set up owing to the lack of uniformity in the flux.



RING FIELD DAMPERS

The forms illustrated in Figs. 3 and 4 are not much liable to eddy current losses and are used with open armature slots when a fairly large air-gap is used. The form illustrated in Fig. 5 is set slightly back of the surface of the pole and is but little subject to eddy current losses. The above dampers are used with poles built up of laminated iron. Where solid poles are used, the surface of the pole itself acts as a damper, but it is subject to eddy current losses.

When machines are operated synchronously there is always the liability that oscillations will be set up between the rotating parts. If these are damped out quickly no harm is done. Excessive pumping not only reduces the stability of the system and renders the machines liable to be thrown out of step, but the resulting corrective currents occasion large copper losses. The function of the dampers is to offer a resistance to the oscillations when they first start and thus prevent their growing to the danger point.

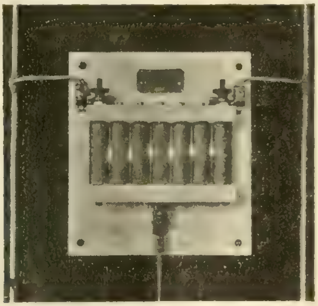
PROTECTIVE APPARATUS

By N. J. NEALL

EARLY EXPERIMENTS WITH LIGHTNING ARRESTERS

The bolt of lightning has ever excited the fears of mankind and frequently destroyed his property.

Early scientists gave much thought to the phenomena of lightning and endeavored to devise a means of protection, but aside from Franklin's classic experiment of drawing a charge from a cloud, and Lodge's experimental solution of the controversy between Faraday and Snow Harris as to the best material and form of lightning rods, little or no advance has been made in the protection against direct strokes of lightning.



DOUBLE POLE NON-ARCING METAL LIGHTNING ARRESTER. INTERRUPTIONS OF A SHORT-CIRCUIT BETWEEN POLES, 1/32 INCH AIR GAP

With the growth of electrical engineering came the discovery that there was something very disturbing to transmission lines even when the lightning did not strike them directly. A stroke of lightning any place in the neighborhood of the line induces disturbances in the wires and often results in the destruction of apparatus.

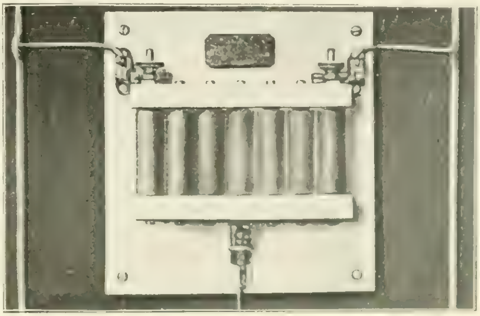
While no attempt whatsoever is made to protect life and apparatus against a direct stroke of lightning, the induced charges which are of much the same nature as the bolt of lightning, may be guarded against very effectively.

It is not generally appreciated that a great deal of scientific research has been made since this new effect of lightning was first announced, nor is it perhaps fully realized that the high voltages which are now employed in transmission lines represent a develop-

ment in engineering with which the lightning arrester has had to keep pace.

Protective apparatus grows more and more important each season. Power plants are rapidly increasing in size and importance—service must continue uninterrupted.

Nothing could more clearly show the nature of the work done in this line by experimenters than a study of the investigation made by Mr. Alexander J. Wurts as recounted by him in a recent talk before The Electric Club.



DOUBLE POLE NON-ARCING METAL LIGHTNING ARRESTER. INTERRUPTIONS OF A SHORT-CIRCUIT BETWEEN A LINE AND THE GROUND

When Mr. Wurts took up the study of lightning arresters for the Westinghouse company in 1890, there were but two arresters in commercial use—the saw-tooth arrester (still used on telephone circuits) and the magnetic blow-out arrester, which was then manufactured extensively by the Thompson-Houston company. The former is a successful arrester so long as there are no heavy currents on the line—for example, in telephone and in telegraph work. For power work this arrester was entirely worthless, since the short-circuit which would follow a lightning discharge could not be broken unless the ground circuit was fused, in which case each discharge of lightning would blow the fuse, thus rendering the arrester of no further service until the fuse was renewed.

In 1847 De La Rive announced that an electrical arc could be repelled by a magnet, and later Elihu Thompson, then of the Thompson-Houston company, patented an arrester based on this principle. The lightning discharge was made to jump an air gap located over a magnet coil. A portion of the line current following a lightning discharge passed through the magnet coil which immediately blew out the arc at the spark gap.

To Mr. Wurts this arrester seemed to solve the problem in almost an ideal way and only a desire to get something as good or better which his company could offer for sale, led him to investigate other means of lightning protection.

One of the first steps taken was the shunting of the fuse used in connection with the saw-tooth arrester, Fig. 1, with a high resistance wire which would take the current after the fuse blew, and because of its high resistance would so reduce the current that the air in the saw-tooth gap could reassert itself and extinguish the arc. This same principle in a more highly developed form is used to-day in the low equivalent arrester. This arrester was, of course, limited to one discharge. Further experiments led to the development of an arrester, shown in Fig. 2, that would automatically reset itself in readiness for another discharge. It operated as follows:

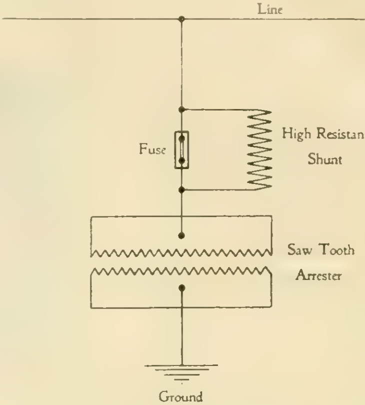
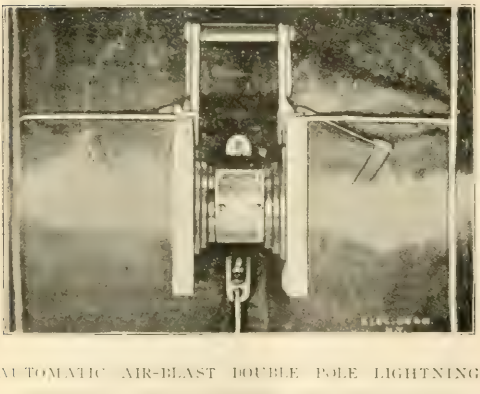


FIG. 1—SAWTOOTH LIGHTNING ARRESTER WITH SHUNTED FUSE

The arc following the passage of a static discharge generates heat and thus the air in the chamber expands. This air rushing up forces the carbon ball violently to the top of tube, and in doing so extinguishes any arc which may have been started under the ball. This entire operation requires but an instant of time and is accompanied by tongues of fire shooting from the holes in the tube and by a sharp pistol-like report.

This arrester would operate satisfactorily only on alternating-current circuits of low power.



AUTOMATIC AIR-BLAST DOUBLE POLE LIGHTNING ARRESTER. THIS ARRESTER WAS ONE IN THE SERIES THAT LEAD UP TO THE DESIGN SHOWN IN FIG. 3

A later design which was the result of several experimental constructions is shown in Fig. 3. This arrester embodied the above principle and was generally quite successful, but it gave some little trouble because a perfect ground connection was necesary. The mechanical action of the arrester depended entire-

ly upon a violent discharge which was impossible to obtain with a poor ground connection.

At one time a complaint came in from a customer that his arresters were not operating properly. A visit was made to the plant and a test was made of the arresters. They failed to blow.

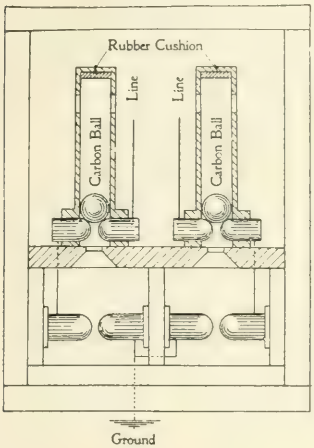


FIG. 2

Apparently all the connections were correct. The operating engineer declared the ground was well made—in fact the ground wire had been connected to a large copper plate which was then thrown from a bridge into the stream near by. A visit to the stream disclosed the plate hanging clear of the water and swinging in the wind. The plate was lowered to its proper resting place and the arresters operated nicely. Only a short time ago a request was made for repair parts for some arresters of this type, so it is assumed that they are still doing good service. Their manufacture has, however, long since been abandoned.

At this time Mr. Wurts devised a method of grounding the generator at each neutral point of the wave by means of a special commutator on the armature shaft, hoping thereby to continually relieve the line of any static discharge which might collect on the system. This method was never used commercially.

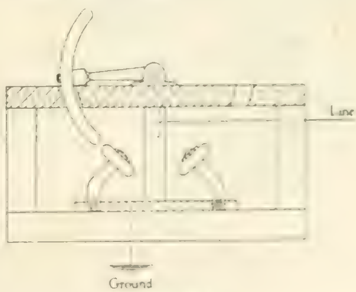


FIG. 3

Another scheme for use on a direct-current system was to have a series of condensers which could be properly charged and discharged and so arranged that one condenser was always taking the static charge from the line while another was emptying it. From these experiments a so-called tank arrester was developed. It consisted of a choke coil of a few turns of heavy wire immersed in a tank of water which was grounded. The coil was connected in series in the line. This arrangement gave rise to a continual leakage, sometimes as much as 3.7 amperes at

500 volts. It nevertheless proved very effective. On account of the electrolytic action of the coils, subsequent design removed them from the tank connecting them at several points with carbon electrodes placed in the tank. This type of tank arrester is shown in Fig. 4, and is quite extensively used at the present time.

By this time experiment seemed to indicate that one single arrester was not sufficient to protect a line. In fact, it was soon concluded that a line should fairly bristle with discharge points and accordingly numerous carbon spark gaps were placed along the line, with a double acting circuit breaker in the station ground wire. This circuit breaker was so designed that when it was thrown open at one contact, it closed at the other. By allowing some little time interval between the opening at one side and the closing at the other side it was supposed that the arcs out on the line would be extinguished, but this did not prove successful. Thinking that the arcs would be more easily extinguished if the gap terminals were made of metal, thereby cooling more rapidly, brass cylinders were introduced in place of carbon, and this marked the beginning of the discovery of non-arcing metal.

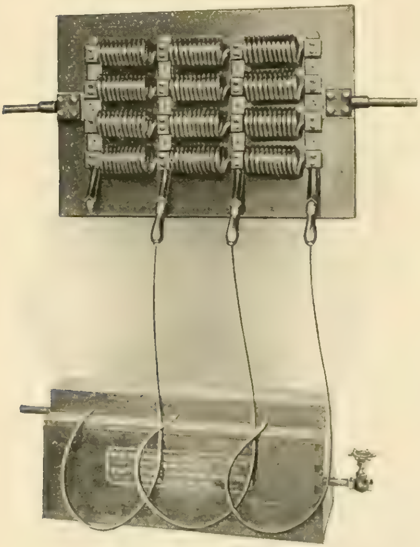


FIG. 4—TANK LIGHTNING ARRESTER

To test this device, called a discharger, the gaps were placed across a line from a 1 000 or 2 000-volt alternator. In series with this line was a switch and a circuit breaker. The test consisted in placing a small strip of tin foil across the gap adjusting the generator voltage, then closing the switch. The operation was successful in the highest degree—too successful, in fact, not to arouse suspicion. The experiment was repeated without the circuit breaker.

The result was a great surprise, for instead of the short circuit which was expected there was merely an insignificant spark. This was repeated many times and so conclusive was the action that, guided by the principle that if a little metal was good more would be better, it was determined to try larger cylinders.

There was present quite an audience of engineers to witness this test, which proved a great sensation. The connections were made as before, and the switch thrown in. The cylinders melted in a great ball of fire like wax. The audience fled. Mr. Wurts was not discouraged, however, and immediately tried the smaller cylinders again, which, to his astonishment, behaved quite as they had done before. All the gaps save one were short-circuited, with the same surprising results. Evidently there was some difference between these cylinders which were apparently alike except for size.

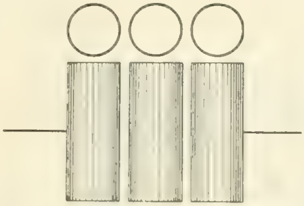
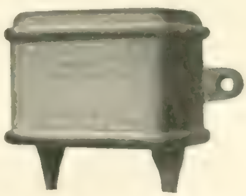


FIG. 5—SPARK GAPS BETWEEN BRASS CYLINDERS. THIS DEVICE WAS USED IN THE EXPERIMENTS LEADING TO THE DISCOVERY OF NON-ARCING METAL

From the department where the cylinders had been obtained it was learned that the larger ones were of cast brass and of a composition of tin and copper, and that the smaller cylinders were of hard drawn brass of a composition of zinc and copper.

It took a number of tests to trace out the effect of the size and the form of the gap as well as the action of various metals. It was found that the size of the discharger did not seem to affect the results so long as there was sufficient metal to prevent actual melting, one-quarter inch brass cylinder melted on the third trial; also it was soon discovered that a very small air gap was necessary for instantaneous interruptions. As the gap was enlarged the non-arcing effect diminished, disappearing with a gap of one to two inches. Nearly every form of gap such as that between spheres, ovals, solid half cylinders, tubes, cubes, etc., was tried with good results excepting in the case of the cubes which showed a slight tendency to hold the arc, but without demonstration.



NON-ARCING LIGHTNING ARRESTER FOR USE ON DIRECT CURRENT CIRCUITS —EXTERIOR VIEW

Of all the metals tried only a few appeared to possess the non-arcing characteristic. Of these the most important are zinc, antimony, mercury and bismuth.

The public was slow to believe in non-arcing metal, and therefore Mr. Wurts, equipped with a spark gap, made extensive tours both east and west demonstrating its operations in power houses—much to the astonishment of the operators.

In order to offer complete protection for a plant this arrester was further developed with choke coils placed in the line. Dr. Oliver Lodge had already shown the advantage of choke coils for holding back static disturbances, and this arrangement was used

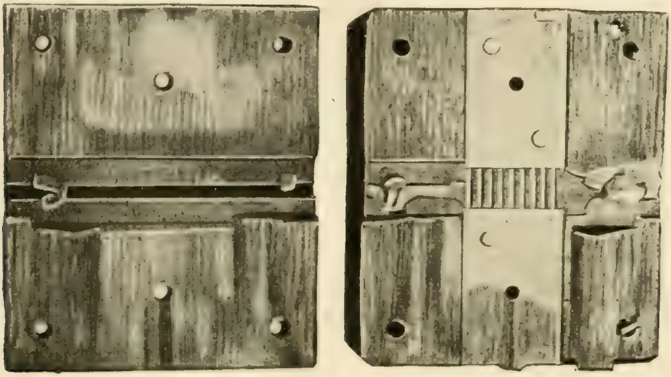


FIG 6—NON-ARCING LIGHTNING ARRESTER FOR USE ON DIRECT-CURRENT CIRCUITS. THE CORE OF THE WOODEN BOX IS HERE EXPOSED SHOWING THE ARRANGEMENT OF THE BRASS TERMINALS AND THE COMB-LIKE CHARRED BRIDGE

for high voltages. These coils, which were probably the first used in connection with alternating current work, make Mr. Wurts a pioneer in the broad application of the principle of the choke coil to lightning arresters and to transmission lines for the protection of apparatus. Shortly after this, tests were conducted in Colorado on a 3 000-volt circuit to prove the arrester under actual service conditions.

Attention was now turned toward the discovery of a non-arcing device that would operate on direct-current lines.

For this purpose an arrester was developed based on the principle that if an arc required space for its formation, then by providing a discharge path which, while allowing the static discharge to pass, would not provide room enough for an arc to form, the desired non-arcing property would be secured.

The final form of this principle is represented by a wooden block containing two brass terminals with a comb-like charred path between them. At first there was no vent canal, and the blocks were blown apart but by the addition of this canal, as shown in Fig. 6, just the right degree of freedom in discharging was obtained. At the same time the formation of an arc was prevented.

MODERN PRACTICE IN SWITCHBOARD DESIGN

PART II

By H. W. PECK

GENERAL CHARACTERISTICS OF MACHINES

TO understand the operation of a switchboard an engineer must be familiar with the general characteristics of the machines and circuits which are to be controlled. Before taking up switchboard practice we will briefly consider these characteristics in standard commercial machines and power circuits. Beginning with direct-current generators, the armature, which is always the revolving part, is a circuit of very low resistance and of low inductance compared to an alternator. The field comprises a number of poles with shunt, series, or compound winding. The shunt winding is designed with a large number of turns and small current carrying capacity, so that at full load and normal voltage the drop through the field winding will be from 60 to 75 per cent. of the machine voltage. In series with the field is a variable resistance, the full value of which is about equal to that of the field and by means of which the field current can be controlled and the machine voltage varied approximately thirty per cent. of normal voltage. The shunt field has great inductance which causes a severe surge in potential if the field circuit is opened with current flowing. This potential is liable to break down the insulation of the field. The standard connections are arranged, therefore, to make it impossible to open the field by switching. One side of the shunt field, usually the negative, is connected to the terminal block of the machine. The other side connects to the variable resistance or rheostat which connects to the positive lead of the machine. When the generator is started the residual magnetism in the field is sufficient to impress a low voltage across the field which then builds up rapidly, the field current and machine voltage mutually reacting to increase each other. As the machine voltage does not increase in direct proportion to the field current, a stable value is reached which is approximately the normal voltage of the machine depending upon the amount of resistance in circuit. When the generator is stopped the field dies out with the speed of the machine. The coils of a series winding are of few turns with low resistance and

current capacity equal to that of the machine. They are connected in series with the armature. A compound field winding comprises shunt and series coils on the same poles. The shunt winding is predominant in its effect and the series winding may either intensify or oppose the magnetism induced by the shunt.

Fig. 3 shows the general form of the curve of magnetization and of the characteristic curves of shunt, series, and compound wound machines. The curve of magnetization plotted between terminal volts and field currents shows the point at which the iron is worked and the small increase above normal voltage which is possible in standard machines. The characteristic of the shunt machine plotted between terminal volts and load shows that the voltage falls in almost direct proportion to the load down to about

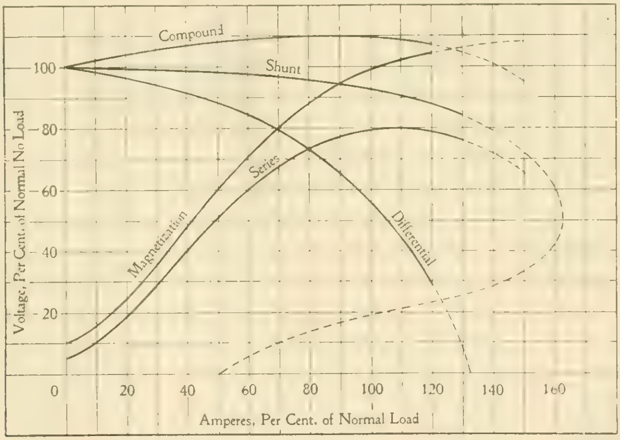


FIG. 3—CHARACTERISTIC CURVES OF DIRECT-CURRENT GENERATORS

seventy percent. of rated load, when the decrease becomes more rapid, and finally a maximum current value is reached beyond which both current and voltage decrease with a decrease in external resistance. It is evident from this curve that the machine will give a very large overload current, but that a short circuit will kill the field and do no great harm. The voltage curve of a compound wound generator rises to a maximum at approximately full load, when it begins to drop. A continued short circuit on this machine will be disastrous as the series coils will maintain a considerable field. A differentially compound wound generator has a more drooping characteristic than the shunt machine and reaches

its maximum current at zero potential. The characteristic of the series generator rises from almost zero voltage at no load to its maximum voltage at about full load and then drops again. It is plotted relative to the magnetization curve instead of to the per cent. scale of no-load voltage as are the others.

The inherent characteristics of shunt machines are such that they will divide the load properly when connected in parallel, as an increase in load decreases the terminal pressure which reacts and tends to decrease the load. With series and compound machines, however, the opposite effect is produced by an increase in load. To run these machines successfully in parallel, therefore, it is necessary to connect their series fields in parallel by a connection of very low resistance so that if the load on one machine increases for any cause a part of the additional current will flow through the series coils of the other machines and raise their voltage correspondingly. This connection between the machine sides of the series coils is called the equalizer, and it is evident that the less its resistance the more closely will the machines divide the load.

A newer type of machine, but one which is considerably used for three-wire direct-current systems, is the three-wire generator. This machine is similar to the standard direct-current machines except that its series coils are divided, half being in the positive and half in the negative leads, and that taps, usually four, are taken from the armature to collector rings. To the brushes on the collector rings are connected auto-transformers, connected to points diametrically opposite each other on the armature, and the middle points of which are connected to the neutral wire of the system. A diagram of these connections showing only two taps and one transformer is shown in Fig. 4. Briefly the action of this machine is as follows: With balanced load there will be only the magnetizing current through the transformers, alternating as the relative potential of the taps changes from positive to negative. With an unbalanced load, for example, a greater load on the positive than on the negative side, the excess current will return by the neutral wire and divide in the auto-transformer, returning to the

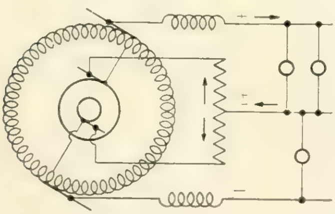


FIG. D—THREE-WIRE GENERATOR SHOWING THE DIRECTIONS OF THE CURRENT IN THE VARIOUS CIRCUITS FOR ONE POSITION OF THE ARMATURE

armature through the collector rings. The action is the same with four taps, but the load is divided in two transformers and distributed in the armature more evenly.

DIRECT-CURRENT SWITCHBOARDS

Fig. 5 shows the standard connections for a small direct-current equipment comprising two compound wound generators and a number of feeder circuits, only two of which are shown. Each

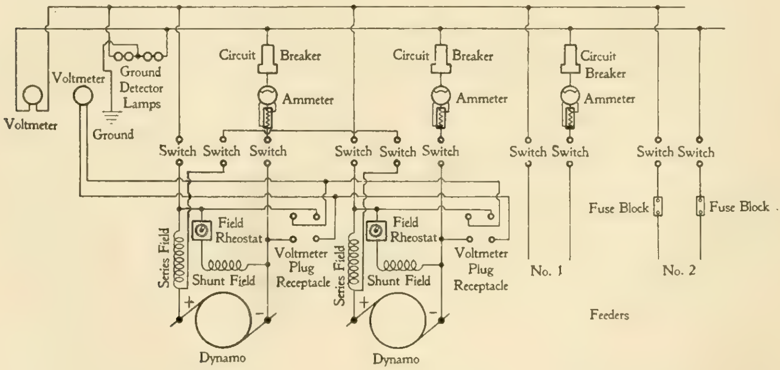


FIG. 5—DIAGRAM OF CONNECTIONS FOR A SMALL DIRECT-CURRENT INSTALLATION

generator equipment comprises one circuit breaker, one ammeter, three single-pole, single-throw switches, one four-point voltmeter plug receptacle, and one field rheostat. We note that there is but one lead from the negative side of the machine, except for the shunt field lead which is a part of the machine and does not affect the external circuit, while the positive and equalizer leads form two paths for the current from the positive brushes. In the negative lead, therefore, is placed the circuit breaker which must measure the entire machine circuit. All of the current carrying parts such as circuit breakers, switches, and ammeter shunts must have a rated capacity equal to the normal capacity of the circuit and must also have a corresponding overload capacity. The circuit breaker has a rated capacity equal to that of the machine, is automatic on overload and may be set to open at any point between 80 and 150 per cent. of normal load. The ammeter scale is calibrated from zero to 150 per cent. of normal load. This not only provides for overload but makes the reading easier under normal loads. The switch in this lead, as also that in the positive lead, has a rated

capacity equal to the normal current of the machine. The order in which this apparatus is connected in the negative lead is determined solely by the convenience of the connections on the back of the switchboard. To the positive and negative leads between the machine and the switches are connected two points of the four-point plug receptacle, the other points being connected to the voltmeter bus wires. There is only a switch between machine and bus in both the positive and the equalizer leads. With only two generators one equalizer switch between them is sufficient, but with more than two there must be one switch for each generator. These switches are usually of the same capacity as the main switches, but may properly be made smaller, say one-half the size of the others, as the current is large only when starting and the differencec in resistance is small. It is not necessary, though it is better, to have the equalizer leads of the several machines of the same resistance.

Switching may be done with three single-pole, with one single-pole and one double pole, or with one three-pole switch. Three-pole switches are seldom used in capacities above 1600 amperes, nor two-pole above 2000 amperes on account of the difficulty in manipulating them. There is furthermore an advantage in having single-pole switches, in that by closing the positive and equalizer switches when one machine is being started up to run in parallel with another, the series field is excited and the field built up more certainly and rapidly than if the residual magnetism is depended upon.

The field rheostat is designed with resistance approximately equal to that of the shunt field winding of the machine. This will allow a range in voltage of about 30 percent. This resistance is divided into as many sections as possible with good design, usually 64 or 78, each section having a contact point on the face plate. The rheostat must be able to dissipate 25 percent. or more of the field less continuously without overheating.

The feeder circuits may be equipped in various ways. Double-pole switches are used in circuits of 2000 amperes or less. In capacities under 600 amperes, if the maximum load exclusive of a fault is known, as in lighting circuits, enclosed fuses are used for overload protection. With circuits of greater capicity than 600 amperes or in which heavy momentary overloads may occur, circuit breakers are used. Some circuits are important enough to warrant the expense of ammeters, others are not. If used, the am-

meter scale is calibrated to 50 percent. above the rated capacity of the circuit.

Connected in series across the bus-bars are several incandescent lamps. Their number is such that under normal conditions half their rated pressure is applied to them, causing very little glow. The middle point of the series is connected to ground. If either line becomes grounded the lamps on that side are short circuited and go out, while the others receive full voltage and burn brightly, affording an automatic indication of a ground on the system. By opening the different circuits in turn and noting when the indication of ground disappears, the faulty circuit is found. There are also supplied for the whole equipment two voltmeters, one direct connected to the bus-bars, the other connected to the voltmeter bus from the plug receptacles. They are calibrated up to 25 or 50 percent. in excess of the normal voltage.

The operation of this equipment is simple. Switches on an idle circuit are always left open. Circuit breakers are kept closed to prevent the gathering of dirt on the contact surfaces. The resistance of the field rheostat is all cut out. The first machine is brought

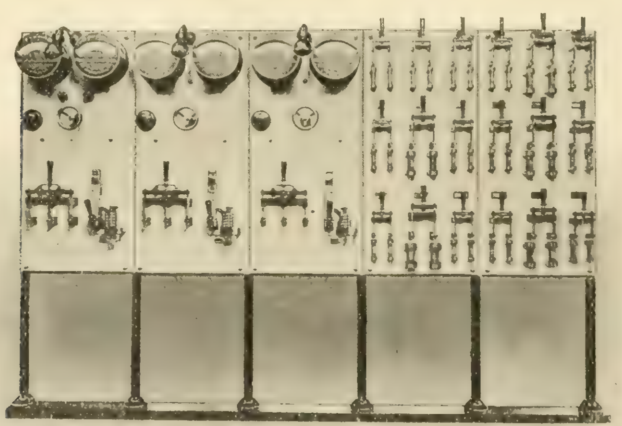


FIG. 6—SWITCHBOARD FOR THREE 150 KW, 125 VOLT DIRECT-CURRENT GENERATORS AND FEEDERS—FRONT VIEW

up to speed and its voltage regulated by cutting in part of the rheostat. The three machine switches are closed and then the feeder switches. When another machine is required, its positive

and equalizer switches are closed if single-pole, the voltmeter plug is insertetd in the receptacle, and the voltage as read on the machine voltmeter is made about three percent. higher than the bus-

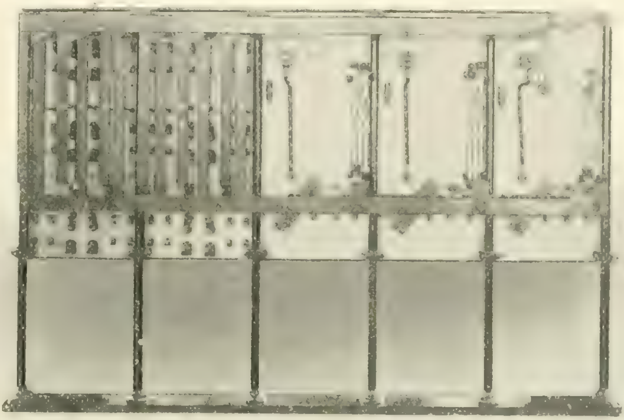


FIG. 7—SWITCHBOARD FOR THREE 150 KW, 125 VOLT DIRECT-CURRENT GENERATORS AND FEEDERS—REAR VIEW

bar voltage indicated on the other meter. The negative switch is closed and the rheostat cut in or out as necessary to make the machines divide the load properly. With a three-pole switch the rheostat must be cut in immediately after closing the switch, as the current through the series coils will increase the machine voltage. If the voltage of one machine be much below the other it may be overpowered and run as a motor. Its direction of rotation will be the same, but sufficient current will be taken to open the circuit breaker. To shut down a machine the rheostat is cut in until most of the load is transferred to the other machine and then the circuit breaker is opened. The three switches are opened and the circuit breaker again closed. All circuits are closed with a switch so that the breaker may be free to open in case anything is wrong, and are opened with a circuit breaker, if there is one, as it is designed for such severe service without injury. Circuits of small capacity may be opened with a switch, but it should always be provided with a quick break attachment for the double purpose of causing less of an arc and protecting the current carrying surfaces from the probable formation of copper burrs.

The equipment for shunt-wound generators is the same as the above except that the equalizer leads and switches are omitted. Series wound generators are used in special cases and will be taken up later.

Figs. 6 and 7 show the front and rear views of a typical board such as is used for an installation represented in Fig. 5. This is a compact, convenient, handsome and relatively inexpensive type of switchboard, but is limited by its size and light construction to circuits of not more than 250 kw. and 250 volts. The panels are four feet high, one and one-quarter inches thick and twenty-two inches wide except in the case of generator panels of the largest capacity, which are two feet wide. In addition to the apparatus shown on the diagram in Fig. 5 an ornamental lamp bracket is supplied for the illumination of the meters on each panel. The face plate and resistance of the field rheostat are mounted at the rear of the panel, the shaft extending through the panel to the handwheel, by which the rheostat is operated. A recent improvement in mounting is the use of a tetrapod bracket. This is an iron casting with four wide spreading feet at one end for supporting the rheostat about twelve inches from the panel, at the other end a flat section drilled for three bolts which go through the marble and dial plate and support the bracket, and between these two parts a hollow shank for the shaft to connect the handwheel and face plate. This mounting simplifies the connections at the rear of the panel, and permits the use of different sizes of rheostat with the same drilling of the panel. The bus-bars are connected to the upper jaws of the switches and circuit breakers so that when open the blades are dead. Neat card holders are usually mounted just above the feeder switches to designate the circuit which they control. All apparatus and connections are designed to meet the rules of the National Board of Fire Underwriters.

ELECTRIC RAILWAY BRAKING

PART IV

BY E. H. DEWSON

THE plain triple valve, which was the original form of this device, and is still in use, is constructed with a cylinder of relatively large diameter and short stroke.

The valve is divided into two parts by an accurately fitted piston, as shown in Fig. 8. The outer part of the cylinder is connected to the train pipe and the inner part is connected to the auxiliary reservoir through the chamber *m*. This chamber contains the slide valve, which is operated by the piston. When the air is admitted to the train pipe, through the motorman's brake valve, the piston is forced to the inner end of its stroke, in which position the feed groove is uncovered and air is permitted to flow past the piston into the auxiliary reservoir. The feed groove is made of such a size that about sixty seconds are required to fully charge an empty auxiliary. The seat of the slide valve has two ports, one leading to the brake cylinder and the other to the atmosphere, and the valve is provided with a cavity in its under surface by which the cylinder ports and the exhaust ports are connected when the piston is at the inner end of its stroke. This is brake release position, and it should be noted

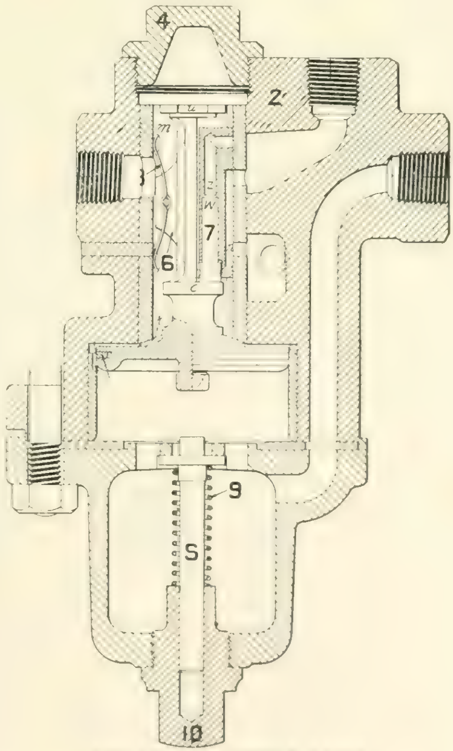


FIG. 8—PLAIN TRIPLE VALVE

that only in this position can the auxiliary reservoir be recharged.

Now if the train pipe pressure be reduced four or five pounds, the preponderance of pressure on the auxiliary reservoir side of the piston will cause it to move outwardly until the stop *j* strikes the flexible abutment 4. In this position, known as *service application*, a graduating valve in the slide opens a small passage *z* from the chamber *m* to the brake cylinder port, and air from the auxiliary reservoir flows into the brake cylinder until the air pressure in the auxiliary reservoir is reduced slightly below that in the train pipe. As there is a small amount of lost motion between the piston stem and the slide valve, the slight excess of pressure now on the train pipe side, moves the piston inwardly far enough to close the

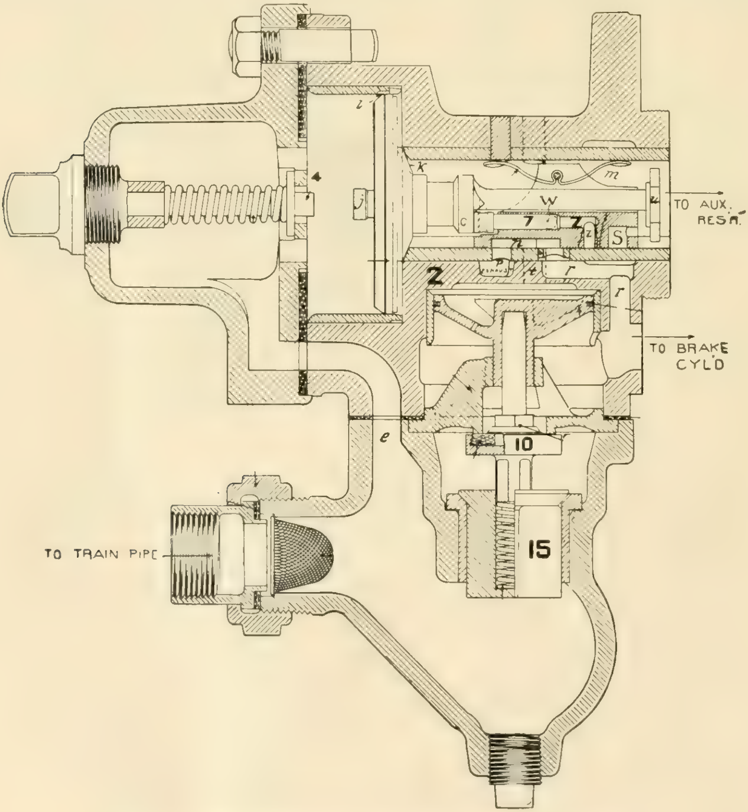


FIG. 9—WESTINGHOUSE QUICK ACTION TRIPLE VALVE

graduating port, but has not sufficient power to overcome the friction of the main slide valve. The triple valve is now in *lap position* with all communications cut off between train pipe, auxiliary

reservoir, brake cylinder and atmosphere. This cycle of operations may be repeated with a resultant increase of the brake cylinder pressure and a decrease of the auxiliary reservoir pressure, until their point of equalization is reached after which any further reduction of the train pipe pressure is not only useless but wasteful.

The brake cylinder pressure may thus be increased step by step until the maximum pressure is attained. If, however, at any step the train pipe pressure is increased a few pounds, the main piston will be forced to the inner end of its travel and release the brake. A sudden reduction of train pipe pressure causes the piston to move outwardly with such force that it compresses the graduating spring and uncovers the brake cylinder port, thus insuring a rapid increase of the pressure in the cylinder.

This type of triple valve operates very successfully on trains of not more than twelve cars, but on long trains violent shocks occur upon making an emergency application, owing to the sluggish flow of air through a long train pipe. On such a train the brakes will be fully set on the forward cars about 18 seconds before they apply on the rear cars. To overcome this difficulty the quick-action triple valve was brought out in 1887 by Mr. George Westinghouse.

Reference to Fig. 9 shows all the features of the plain triple valve, but in addition there is in the slide valve seat a third port about three times as large as the brake cylinder port and leading to the emergency piston *S*. When an emergency application is made, this port is uncovered as well as the port leading to the brake cylinder, but the air pressure increases so much faster on the auxiliary reservoir side of the emergency piston than on its opposite side toward the very much larger brake cylinder, that this piston is forced down. This movement unseats the emergency valve 10, which permits air from the train pipe to rush through the check valve 15 into the brake cylinder until checked by the flow from the auxiliary. The cylinder pressure due to an emergency application of the Westinghouse triple valve is 60 pounds, while 50 pounds is the maximum attainable from a full-service application. This difference of pressures is entirely due to the air which was vented into the empty brake cylinder from the train pipe. The local venting of air from the train pipe during an emergency application produces a wave of pressure reduction through the entire length of the train pipe, so that with a fifty-car train but three seconds elapse between the movement of the brake valve handle and application of the brake on the last car.

The standard New York quick action triple valve is shown in longitudinal diagrammatic section in Fig. 10. In service action it is similar to the Westinghouse valve except that a sliding form of graduating valve (48) is used, instead of the Westinghouse pin valve (7-Fig. 8). With this valve quick action is obtained by the main piston 128 moving outward so quickly that the air in chamber *G* cannot escape through port *F* rapidly enough to prevent the piston 129 moving with it and unseating the vent valve (71). This permits air from the train pipe to flow into the cavity *H*, and force the quick action valve piston 137 to the end of its stroke. It escapes to the atmosphere through port *J*. At the same time piston 137 unseats the quick action valve 138, thus opening a large passage from the auxiliary reservoir *K* to the brake cylinder through check valve 117. Thus with this valve a quick application of the brakes throughout the train is obtained, but as the traine pipe is vented to the atmosphere, there is no increase of cylinder pressure in emergency over that of maximum service application.

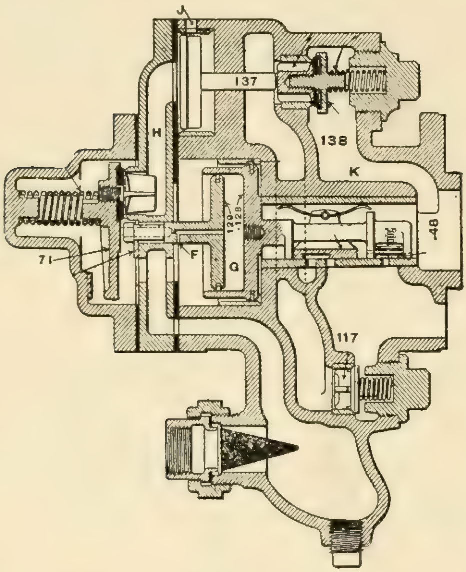


FIG. 10—THE STANDARD NEW YORK QUICK ACTION TRIPLE VALVE LONGITUDINAL SECTION

With the standard Westinghouse triple valve and the New York Air Brake triple valve the auxiliary reservoirs are so proportioned that when equalized into their brake cylinders with the pistons, at eight inches stroke, the resultant pressure is fifty pounds, consequently a 20-pound reduction of train pipe pressure gives a full-service application.

OPERATING VALVE

The motorman's brake valves provide a means for varying the train pipe pressure to operate the triple valves as described above. This necessitates the following combinations:

(1) Release position, for charging the train pipe and auxiliary reservoirs, and consequently releasing the brakes when set. In this position pressure from the main reservoir is admitted to the train pipe.

(2) Lap position, with all ports closed.

(3) Service application, with a small opening from train pipe to atmosphere.

(4) Emergency application, with the train pipe fully opened to atmosphere. In lap, service, and emergency positions the main reservoir is entirely cut off from the train pipe.

These four positions are marked in the notch plate of all automatic operating valves. The deepest notch, at which only can the handle be removed, marks the lap position. All notches from the lap position notch in counter clockwise direction, viewed from above, are for application of the brakes, and those in clockwise direction are for release.

In the New York and Westinghouse brake valves, following steam railroad practice, the release position is divided into two steps, the one next to lap being called the running position. With the handle at this notch the air from the main reservoir passes to the train pipe through a pressure reducing valve called the feed valve, which gives a differential of about twenty pounds between reservoir and train pipe pressures. When the handle is at the release position, the feed valve is short circuited and the 80 to 90-pound reservoir pressure is admitted direct to the train pipe; this serves to give a quick release on long trains, but obviously the handle must not be left long in this position, else the high main reservoir pressure will overcharge the auxiliary reservoirs. When the handle is placed on running position with the auxiliary reservoirs overcharged the train pipe pressure will probably drop down to 70 pounds on account of leaks, and the brakes will go on with a force directly proportional to the amount of overcharging. When an application of brakes is made with the auxiliary reservoirs overcharged, an excessive cylinder pressure may be obtained, and the brakes will not release upon restoring the train pipe pressure to 70 pounds. It is then necessary to bleed the auxiliary reservoirs.

Service position is sometimes divided into two parts, intermedi-

ate and full, the difference being that in the former the opening from the train pipe to the atmosphere is smaller than in the latter. This is to compensate for the greater pipe volume on long trains than on short ones, so a given time interval will have approximately the same effect in reduction of pressure in the one case as in the other.

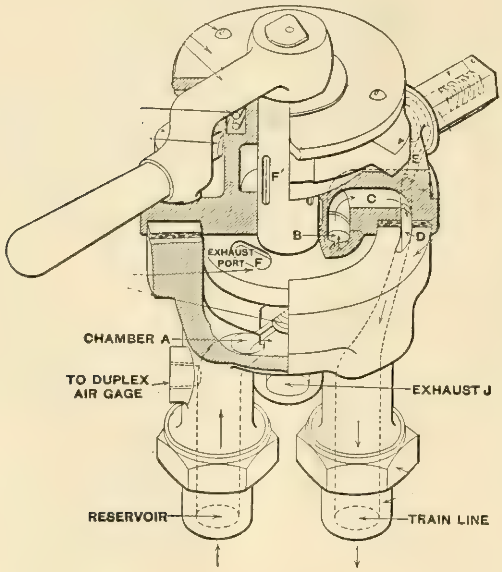


FIG. 11—NEW YORK MOTORMAN'S VALVE

Fig. 11 shows the New York motorman's valve partly in section, and it will be noted that the rotary valve is beneath the fixed valve seat. With this arrangement the exhaust is made through the valve stem, and as the reservoir pressure is on the other side of the valve, the valve stem requires no packing.

Fig. 11 shows the location of the various ports in the valve and the seat, with the handle at running position. The release port B, Fig. 12, shown in dotted lines, passes through the valve, and the exhaust port F leads from the face of the valve to its hollow stem and thence to the atmosphere. Port C is located in the valve seat and leads directly to the train line, while the feed port E, also in the valve seat, connects with the train line through the feed valve which is located higher up in the seat casting. The other positions of the valve may readily be figured out, bearing in mind that ports F and B rotate together. Port C is formed with a tapering or tail-like opening by which small reductions in train pipe pressure for service applications can be made through the exhaust port F.

The feed valve, which in running position gives a fixed differential between the main reservoir and the train pipe pressures, is of very simple construction. As shown in Fig. 12 it consists of a poppet valve held to its seat by a spring of such a strength that

a pressure of twenty pounds per square inch is required to lift it. In electric service this type of feed valve has the disadvantage that a reduction in the main reservoir pressure from whistling prevents the valve from feeding air into the train pipe until the train pipe pressure has dropped to twenty pounds below that of the main reservoir. Now, if this drop takes place through leakage in the train pipe, the brakes are liable to set.

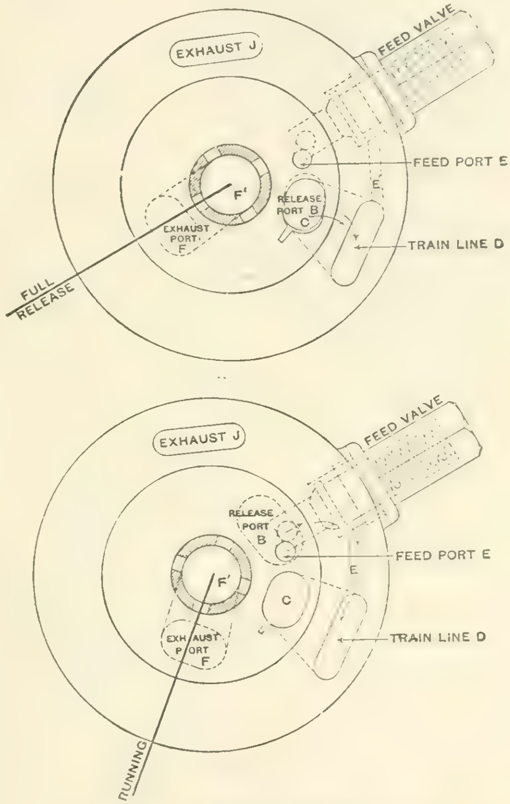


FIG. 12— NEW YORK FEED VALVE

Fig. 13 shows a distorted diagrammatic view of a slide-valve feed valve, which maintains a constant train pipe pressure so long as the pressure in the main reservoir is higher. The passage *f* is in communication with the main reservoir when the brake valve is in running position, and *i* connects direct to the train pipe, so its pressure is always on the diaphragm 57. The pressure on this diaphragm is opposed by a spring so adjusted that at seventy pounds pressure valve 59 is permited to close the port *a*, but at any lower pressure this valve is raised from its seat. On charging the train, the main reservoir pressure entering at *f*, forces the piston 54 outwardly, thereby uncovering the port *b*, which permits air to flow into the train pipe. At the same time, the air which leaks by the supply-valve piston 54, passes through the port *a* to the train pipe. As soon as 70 pounds pressure is attained in the train pipe, the regulating valve 59 closes and the pressure is equalized on the two sides of the piston 54, which permits the spring 58 to move the

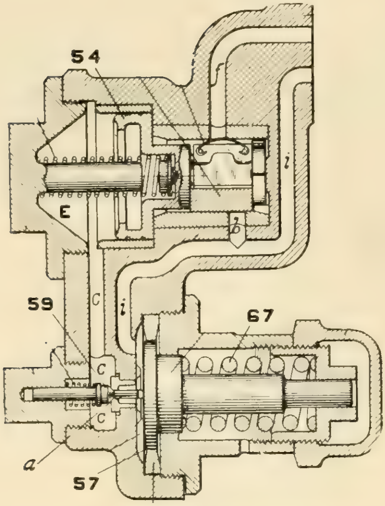


FIG. 13—WESTINGHOUSE FEED VALVE

supply valve, closing port *b*. Upon a reduction of the train pipe pressure, the regulating spring 67 opens the port *a* and the reduced pressure in the chamber *E* permits the supply valve to open port *b* until the normal train pressure is restored, when this port is again closed, as explained above.

With the main supply valve of the sliding type, and the little regulating valve having its air strained past the closely fitting piston, this form of feed valve is very free from the trouble of train pipe pressure creeping up

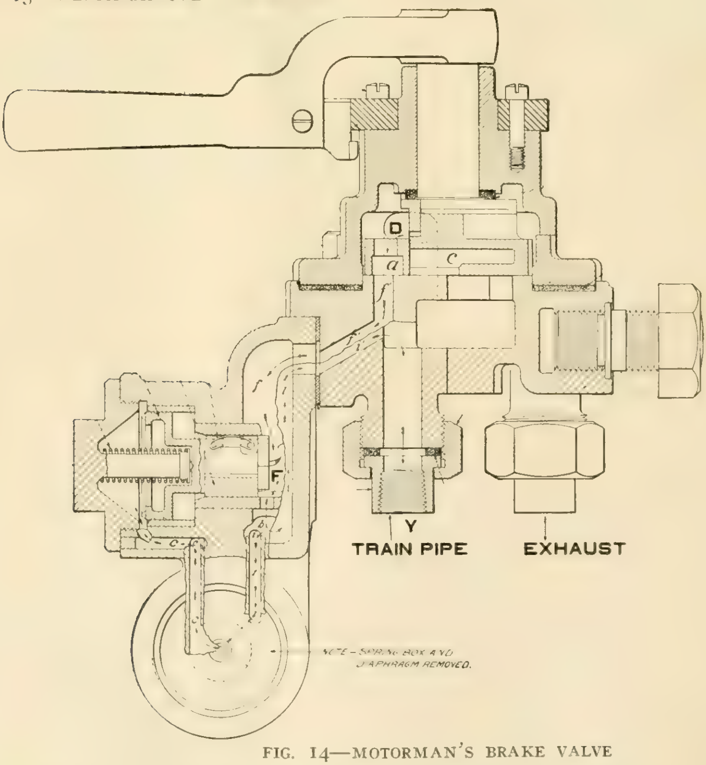


FIG. 14—MOTORMAN'S BRAKE VALVE

due to leakage caused by dirt. The location of the valve on the motorman's brake valve is shown in Fig. 14, in which the handle is in running position.

FACTORY TESTING OF ELECTRICAL MACHINERY—XII

BY R. E. WORKMAN

APPROXIMATE DETERMINATION OF REGULATION FROM OPEN-CIRCUIT SATURATION AND SHORT-CIRCUIT TEST.

In cases where it is impracticable to obtain the regulation curve directly, an approximation may be made from the open-circuit saturation curve and the armature short-circuit curve. The

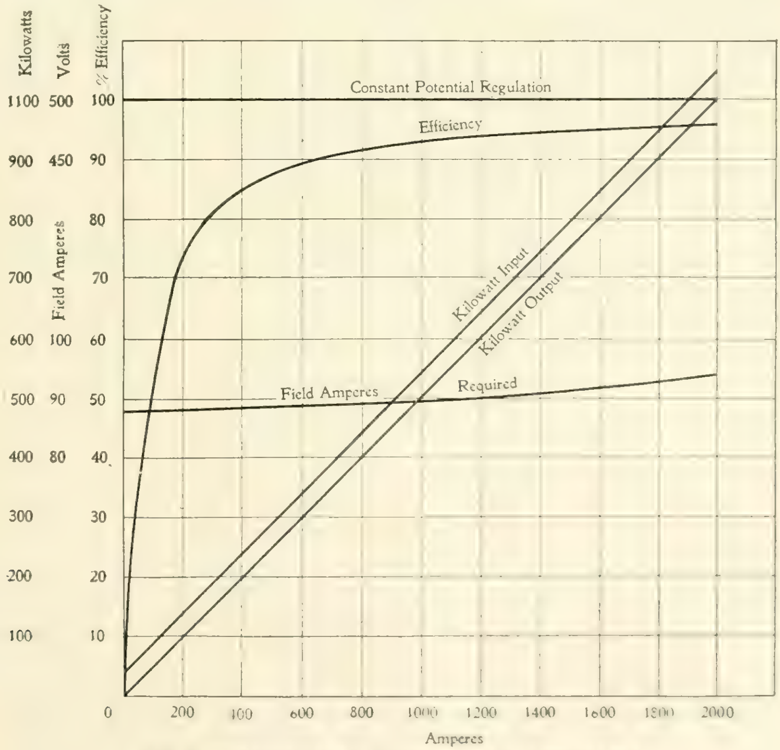


FIG. 65—PERFORMANCE CURVES OF AN ALTERNATOR

method of computing regulation recommended by the Standardization Committee of the American Institute of Electrical Engineers is as follows:

Add the armature resistance drop for a given load to the ter-

minal voltage on open circuit. From the no-load saturation curve determine the field current corresponding to this voltage and add this field current vectorially to the field current required to produce the same load with the armature short-circuited, these two quantities differing in direction by 90 degrees. Then from the open-circuit saturation the voltage corresponding to this resultant field current is found. The difference between this voltage and the terminal voltage of the armature at the chosen current, expressed as a percentage of the latter, is the regulation of the alternator for that particular current.

In Fig. 65 is shown the regulation, calculated in this way, for the 1 000 kilowatt, 500 volt alternator, the saturation and short-circuit curves of which are given in Fig. 54, November JOURNAL, p. 615. This calculation is carried out as follows:

The armature resistance from terminal to terminal at 50 degrees centigrade=0.00405 ohms.

The current per phase at full-load=1 154 amperes.

The $I R$ drop at full load is found as follows:

The resistance of one of the windings of the alternator from the center of the star to a terminal is half the resistance from terminal to terminal, in this case is equal to 0.002025 ohms. The current in this winding is 1 154 amperes, so that the drop in each leg of the winding is 2.34 volts. Since the two legs are 120 degrees apart, the drop from terminal to terminal will be $\sqrt{3} \times 2.34 = 4.05$ volts.

The field amperes at 504 volts from the saturation curve=88.8.

The field amperes at 2 000 total amperes on short-circuit=30.

The resultant field amperes$=\sqrt{(88.8)^2+(30)^2}=93.8.$

With this field current the open-circuit voltage, from the open-circuit saturation curve would be 527, so that the inherent regulation for full-load with constant field current would be 5.4 per cent.

The regulation curve shown in Fig. 65 is that for constant potential, so that it is only necessary to calculate the field amperes required, with a number of different currents, to give the full terminal e.m.f. of 500 volts, this being done as described above. From the values found, the curve shown in Fig. 65 may be plotted. The regulation curve with constant field current, which is sometimes desired, may be found as follows: The field amperes (93.8) required to give full voltage at full-load current are calculated as before. From the saturation curve the no-load voltage (527) cor-

responding to this field current is read, giving another point on the e.m.f. regulation curve, as well as the inherent regulation of the generator. Other points may be found, if it is remembered that the total field amperes are equal to the square root of the sum of the squares of the field amperes required to give the full voltage on open-circuit, plus the *I R* drop in the armature, and the field amperes in the short-circuit test, corresponding to the current under consideration.

Referring to the calculation previously given:

The constant field current=93.8 amperes, giving full voltage at full-load current.

At 1 000 amperes, say, the short-circuit field current=15 amperes. Then the field current producing a magnetizing force in phase with the current, *i. e.,* symmetrical with respect to each pole, will be $\sqrt{(93.8)^2-(15)^2}=92.5$ amperes.

The potential difference, therefore, will be found by subtracting the *I R* drop at 1 000 amperes, total, from the terminal e.m.f. corresponding to a field current of 92.5 amperes taken from the no-load saturation curve. The result of this process will be a potential difference of 520 volts. In a similar manner, other points on the regulation curve may be calculated and plotted.

OIL SATURATED COMMUTATORS

BY A CONSTRUCTION ENGINEER

I AM occasionally called upon to repair burned-out commutators. In some instances, I am given glowing accounts of how perfectly the machine has always operated, and of the careful attention that has been paid to every detail that could possibly affect its operation. But such a machine will occasionally, without any warning whatsoever, begin to smoke at the armature, and before it can be shut down, develop a pin wheel of fire at the commutator, throwing molten copper in every direction.

The real cause of the trouble does not appear until some of the V mica is removed from the commutator, when it is observed that the mica is saturated with oil. Even then the argument is sometimes put forth that the commutator has never been oiled to an extent that would saturate the V mica; also, that oil is a first-class insulator.

In one instance, that of a 400 kw, 250-volt engine-type generator, a short-circuit occurred between bars at three different points on the commutator, but did not damage the V mica. It required only a new insulation between the commutator bars to repair the damages. Investigation showed that the engine had been throwing oil on the end of the commutator.

In another instance the commutator and armature of a 1 500 kw, 550-volt generator operated by a cross-compound engine was badly wrecked by a short-circuit occurring at the bottom of the commutator bars. About twenty of the bars were burned, three of which were burned through to the surface, making an opening through which the molten copper was thrown the entire length of the power house. This violent short-circuit burned some of the armature coils so badly that their ends caught on the pole pieces. Before the machine could be shut down some fifty coils were damaged.

In erecting the engine of this unit, the oil guard ring had been omitted from the end of the shaft adjacent to the generator. During the one year that it had been in operation, oil had found its way to the mica insulation of the commutator, carrying some dirt with it and possibly some of this oil had become slightly carbonized, thus greatly weakening the insulation.

In a burn-out of this kind the metallic vapor, formed when the short-circuit is started, is under considerable pressure and is apt to penetrate the insulation underneath and between the commutator bars, sufficiently to leave little globules of metal deposited in the mica. Thus a similar trouble is liable to occur after the burned places are repaired and the oil-saturated mica replaced. In some cases the trouble can only be overcome entirely by renewing the insulation of the commutator throughout.

SHOP EXPERIENCE

ITEMS FROM THE NOTEBOOK OF THE APPRENTICE

NOTES ON SOLDERING

CLEAN and hot are the two essentials for a good soldered joint, and must be kept in mind in every job. In making an ordinary spliced joint, the wires are each bared of insulation for a distance of about one inch from the joint and carefully cleaned by the use of sand paper or emery cloth. The emery

cloth is preferable because it is so tough and flexible that a rapid scouring of the surface can be made.

The two ends of the cleaned wire are butted together after slipping over them a carefully cleaned sleeve. The surfaces may be brushed with a solution of sal-ammoniac, or what is preferable, coated with a soldering paste. A solution of resin in alcohol is sometimes employed for this purpose. The joint is now ready for the application of the solder. It is heated by a hot soldering iron or in the flame of a hand-torch until the application of a soldering stick to its surface shows that the solder will readily flow over the cleaned surfaces. Certain precautions must be observed in heating the joint, as, for instance, not to get the surface too hot, as the copper will then oxidize. Neither must the surface be too cold, as the solder will not then readily flow, as a consequence of which the joint may be imperfectly united, or because of frozen drippings, it will present stalactitic points which have to be cut or filed off before taping the joint. It is absolutely necessary that the soldered joint have a smooth surface, otherwise the insulation will be cut.

If, however, the joint need not have mechanical strength and is only required to be electrically conducting the use of a sleeve may be dispensed with. The wires may then be placed side by side overlapping and wrapped with fine copper wire, about No. 26 in size. The fine wire holds the joint in position. Care should be used in wrapping that the wrapped wire present no sharp points. Solder is now flowed on as before. After a sufficient amount has been put on to cover the surface, and the interstices of the fine wire are filled, it is advisable to wipe the joint with a cloth just as a plumber does in wiping a joint. This removes any excess of solder and makes the joint smooth on its surface.

If the conductor is two wires in multiple and it is desired to solder it to a similar pair of wires, it is usual to cut one wire of each pair half an inch to an inch shorter than the other and then place the two conductors together. These may be wrapped as above and their soldering presents no difficulty. Obviously, this may be extended to the soldering of any number of conductors in parallel.

It is sometimes necessary to solder a sheet copper strip to a wire in order to provide a flexible lead for wires of large size. After the surfaces are cleaned one end of the copper strip is formed to fit the wire to which it is to be soldered. After fluxing the

soldering operation is performed as usual. If a single copper strip does not provide sufficient conductivity for a wire cable, two or more of them are placed in parallel upon it, in which case difficulty is apt to be experienced from the flowing of solder between the strips.

Solder will always run on hot copper. To obviate this difficulty it is usual to place strips of material between the sheets of copper to prevent their being united by the flowing solder.

Copper wire up to the size of No. 0, may readily be soldered by a soldering iron of the usual size, say an inch and a quarter square. With larger size a torch must be used unless one has a pot of hot solder with a couple of ladles, when the hot solder may be poured from the ladle directly on the joint. This can be accomplished by pouring upon the joint and catching the drip in the ladle underneath the joint. If the joint is of such a size that it is not warmed at the first pouring, the lower ladle may be brought over the joint and a second pouring may be made. This process is to be continued until the joint is thoroughly hot, which will be apparent from the fluidity of the molten solder running through it. If a sufficient amount of solder is not retained in the joint, as may happen if the joint is too hot, it may be filled in from a small stick of solder and then wiped as it cools to secure the requisite smoothness.

In soldering one cable to another cable it is usual to interleave the fine wires to a sufficient length and then wrap the whole with fine wire, after which it may be treated in the usual way. When a cable is to be inserted in a sleeve or a terminal plug it may be dipped in the soldering fluid and then pluged into molten solder. The plug in which the cable may be placed can be tinned in the same manner. The receptacle of the plug is now filled about half full of solder, when the tinned cable may be plunged into it. The parts should be solidly in position and remain undisturbed until cooling has taken place.

A SLIDE WIRE RESISTANCE

In the calibration of testing instruments it is extremely useful to have a fine adjustment on the low resistance which is usually employed in making a calibration. A slide wire resistance spool of a portable form readily carried in the pocket or the hand, may be made by winding upon a cylinder of wood or fibre some No. 20

German silver wire. The cylinder should be about two inches in diameter and from twelve to twenty inches in length. This will give a spool of a total resistance of 10 to 15 ohms.

At each end of the cylinder place a small bracket to support a brass rod parallel to the cylinder. One terminal wire is fixed to the rod as shown at the left of the illustration. A terminal wire is also brought out from this end of the resistance spool. A contact rider shown at the right of the spool makes a good electrical connection between the brass rod and the resistance wire. By sliding this contact rider along the spool, any given length of resistance may be secured between the terminals.

Another sliding contact shown at the middle of the rod makes good electrical contact with the spool wire, but is insulated from the brass rod. It carries a terminal wire which is at the middle point of the resistance.

This third terminal is used when close adjustments of the resistance are required. In using it the two terminals at the left are joined together to constitute one connection and the middle point is used as the other connection. This places the two parts of the resistance wire on either side of the middle point in parallel. After the resistance is approximately fixed by shifting the end contact the final adjustment is made by shifting the middle point of the resistance.

EDITORIAL COMMENT

The New Year

"This magazine is not directed to a scattered and unknown clientele, but it is precisely and definitely for young electrical engineers—young men who are making it their special business to fit themselves for effective engineering work."

The keynote of the announcement issued a year ago sounds the New Year's resolve for the coming year.

Young engineers need a good equipment of theory and of facts. But the JOURNAL does not aim to be a text book (though one college boy says, "It's the best text book we've got") nor a handbook of electrical data. Theory and data are essential, but they are the frame work, the skeleton. The JOURNAL deals with the apparatus and the operation. It is not so much an electrical anatomy as it is an electrical physiology. Mathematical theory and clock face diagrams are not the essential things which beautiful experiments merely illustrate. The operating machine, the physical real thing is of all consequence and the diagram and formula are useful only as they explain its action and make it clear. They are convenient modes of expressing material facts and physical conceptions. If "very few young men have a definite concrete idea of alternating currents," it is high time that they did. We aim to aid in developing definite physical conceptions.

Electrical engineers must be alert, awake, active and keep abreast of the advances in electrical engineering, hence the need of an up-to-date monthly. Readers of the JOURNAL have noted the stress which has been laid on things which are not within the pale of the text-book nor the ordinary range of technical practice. An engineer must be a man; a great engineer must be a great man. The human element is apt to be overlooked—especially by young men. But it is the effective element. The non-technical articles have not been put forth by the theorist on moral grounds; they have been written by experienced engineers and men of affairs to emphasize the essential elements in an effective career.

Our aim, therefore, is to be of service to the young engineer —and it is hard to find an electrical engineer who is not young— in making him a better engineer and a broader man. A Journal of Engineering and a Journal of Inspiration.

Ginger

"I know the vigorous, restless spirit in your family and I like it intensely. You will be somewhat handicapped in selling for us by reason of the fact that we are a large organization and have to be very systematic, so that side deals and verbal promises, which can sometimes be made for a jobbing house, cannot be made for us. If you can keep within these conditions I prophesy a good future for you."

The above was written in reply to an application for a position

in the sales department by a man wanted not so much on account of his success in selling for a supply house, but because he was a positive character with the right material in him.

I had seen the man play baseball. It did not matter where he was, he got under the ball if it was any way possible, irrespective of cost or worry as to what he would do with the ball if it should reach him. When he was nearly in the right place he found himself, gathered all his faculties to complete the play. Every muscle in his body was servant to his mind. His faculties were all at his instant command. He slid bases as though a frosty or muddy ground was his favorite element. The subsequent conditions of his clothes, personal appearance, the good-will of the grandstand counted for nothing. As a batter he hit hard, or sacrificed with rare judgment; victory for his side was the only thing that he had in mind.

Men with these qualities are not altogether unusual, but the number of them that make a success of life is not large. They live under tremendous temptations and when they first turn their ear to flattery their career terminates. The failure is not due to the qualities which the man has. He fails because he has not met the problems of life with a determination to be master in his particular field. He has not become thorough. He has thought his physical energy would excuse him from thoroughness of knowledge. He has plunged into things for which he was not fitted. He has not realized that thorough knowledge of his subject is the only enduring key to success.

In a great corporation educated men are very apt to have this belief, that exact knowledge is the first requisite, but they fail in the other qualities that this applicant possessed. A great company is not going to take care of anybody; it is not going to push him forward; he has no right to expect that it will. He is given a fair chance and that is all. If he expects anything more he is disappointed. He does not sacrifice himself enough and bring out his positive qualities enough. There is no man so helpless as a leaner. Young men with knowledge need ginger. They must come in contact with men and in every position that they attain they must excel. They must make themselves indispensable. The man who gets to the top gets there himself and is not put there. Young men in a great corporation should realize that they are immature, that they need some time to ripen, but they should also realize

when the time comes for them to find themselves and become competent men. Just as soon as they realize this it is going to be evident to everybody about them. In such corporations men are going to be paid what they earn, no more, no less.

There are a great many fairly good men in the world, but the best men are rare and greatly in demand, and the best men are those with ginger added to knowledge. Every big corporation needs all the best men it can get. Teachers can do a great deal, but they cannot make young men old and there is no way to transmit experience. This comes from labor and from nothing else. Nobody wants a passive man, while a competent man with ginger is indispensable.

FRANK H. TAYLOR.

Lightning Protection

A few years ago a gentleman visiting a college laboratory saw a number of friction machines, Leyden jars and the like and made the remark that all that kind of electricity had gone out of date. The professor to whom the remark had been made stated afterwards to one of his students that really all electricity was the same kind and that the principles of static electricity really underlay and were fundamental to electricity in its ordinary commercial or dynamic form.

One who is familiar with only one phase of a subject is apt to be very much surprised and bewildered when he encounters phenomena with which he is not familiar. For example, the battery electrician is liable to violent surprise if he short circuits bus bars to see if he can get a spark. The direct-current man is thrown into perplexity and mental distress when in the early stages of his experience with alternating-current he encounters a low power-factor. So also the engineer who is familiar with ordinary commercial currents finds something quite astonishing and inexplicable in the discharges between terminals or through insulation which is practically immune to the stresses of normal operation. Such abnormal dynamic conditions, however, occur elsewhere than in electric circuits. A piece of glass, a line insulator for example, may be able to stand enormous mechanical pressures and have a sufficient rigidity to support a long span of heavy wire. But it may be shattered by a blow from a tack hammer or by a bullet. A water pipe which may stand a very high pressure test may be bursted by the instantaneous pressure due to the water hammer developed by the sudden shutting off of the water.

These impulses, these static strains, the equalizations of pressure that occur throughout an electrical system when the potential at some point is suddenly changed, may be investigated either mathematically or physically. The mathematical treatment is quite abstruse and aside from the difficulties which are purely mathematical, this method has great limitations in that the constants needed in a numerical solution of equations are very difficulty to secure in real conditions, i. e., in commercial apparatus and transmission circuits. The mathematical method has a very considerable value in getting at the general relations and the general theory of the subject, but it has little interest for the average engineer as distinguished from the expert. What most men want is a physical common sense understanding of the character of these lightning and other discharges in order that they may have a reasonable understanding of them which may enable them to avoid their disastrous results.

An article in this issue of the JOURNAL gives an interesting account of some forms of protective apparatus which have been used from time to time in the past. It is interesting to note how lightning arresters which were effective in certain plants have become inadequate as generators have become larger and voltages have risen higher. It is instructive also to see the evolution from for to form, and the results which have followed a painstaking, scientific, experimental study of this subject as conducted both in the laboratory and in the field. It is expected that this article will give a clear physical understanding of many of the characteristics of lightning and static discharges, and also a statement of the ways in which these conditions are met in commercial protective apparatus. The field is a most interesting and fascinating as well as an important one, which assumes still greater importance as higher voltages are employed on longer lines and the dividend necessity for absolutely continuous service is more clearly seen.

CHARLES F. SCOTT.

The Shop Course

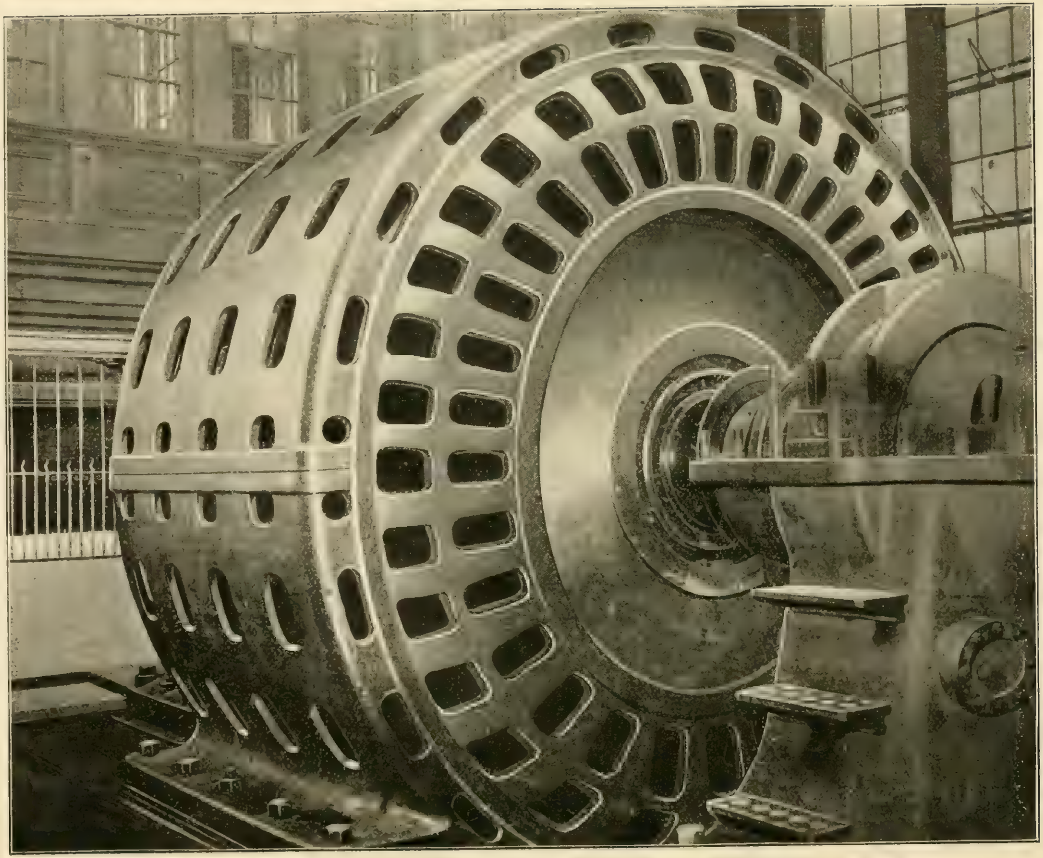
Mr. Damon, a prominent electrical engineer and Chairman of the Chicago Branch, A. I. E. E., in his excellent paper on "Opportunities in the Electrical Business," raises some pertinent questions regarding the shop courses established by large companies for training young men.

He indicates failure, in that only about 25 per cent. of the shop

graduates are selected by the large companies for their own use. The percentage in the Westinghouse works, however, is considerably greater—nearer 75 than 25 per cent. Nevertheless, granting the point that something is wrong, is the alleged fault with the system, or is it with the company, or is it elsewhere? A commission is proposed for improving the facilities for "getting experience." Doubtless good suggestions would result, but there is another element. Mr. Damon is discussing opportunities. Is not the shop course one of them? Is he not pretty close to the solution when he says, "it depends largely upon the man?" How few freshmen receive diplomas at the end of four years and how few graduates are notably above the average after ten years!

Men who are not naturally fitted to be engineers are given a narrow engineering education. Some cannot even write good English nor think logically, nor work effectively. They will not make pure engineers; but their education and training has had nothing else in view. The proposed commission may well study the preparation of the grist that comes to the mill as well as the efficiency of the mill for "getting experience."

By a fortunate coincidence Mr. Taylor's spicy editorial appears in this issue and will afford to many minds a flood of light on the reasons for the success or the failure of young men who take a shop course.



5,500 - KW., 25-CYCLE, THREE-PHASE, 11,000-VOLT, 750-R.P.M. TURBO-GENERATOR IN OPERATION AT THE SEVENTY-FOURTH STREET STATION OF THE INTERBOROUGH RAPID TRANSIT COMPANY, NEW YORK

THE

ELECTRIC CLUB JOURNAL

VOL. II FEBRUARY, 1905 NO. 2

PARALLELING THE LARGEST TURBO-GENERATOR IN SERVICE

IN the latter part of December, 1904, a 5,500-kw., 25-cycle, turbo-generator built by the Electric Company was put in operation in the Seventy-fourth Street Station of the Interborough Rapid Transit Company, New York. It was the first Westinghouse unit of this size to be put in service, although a number of similar machines are approaching completion. The next day after this machine was put in service, it carried loads as high as 8,000 kw., and for considerable periods loads between 7,000 and 8,000 kw. were of common occurrence. This turbo-generator is the largest now in service.

Within a few days after the machine was put in service, and while operating in parallel with six of the slow-speed, 5,000-kw. machines in the same station, a short-circuit occurred among the main leads at a point between the turbo-generator and the switchboard. This was a dead short-circuit and it tripped the automatic switches on all the slow-speed machines, which were set at almost three times full-load current, but did not trip the safety switches on the turbo-generator on account of the fact that the arc was so violent that it burned off the leads to the safety devices for this particular machine, though these leads were in a separate conduit. It was necessary to cut the turbo-circuits off by hand and the short-circuit therefore continued on this machine some little time before it was cut out. Careful examination of the generator showed that it was absolutely uninjured in any way, as far as could be determined, and was ready for service immediately afterwards, but could not be thrown in with the other machines on account of the main leads to the switchboard being burned off.

The machine has been in service with heavy loads since these leads were replaced.

The 5,500-kw. turbo-generator is run in parallel with the other machines in the station and the only notable difference in its operation and that of the slow-speed machines is due to the difference in the speed regulations of the two types of engine. The steam turbine was adjusted so that it regulated much more closely in speed than the low-speed engines and, in consequence, the turbo-generator takes the fluctuations in load. It is noted that when the turbo-generator is operating in parallel with the slow-speed machines, that the latter machines carry a much steadier load than when the steam turbine is cut out, the turbine unit appearing to take all the fluctuations when it is in circuit. This unit, therefore, has something of the effect of a fly-wheel or a storage battery on the system. This effect, if considered undesirable, can be modified readily by adjusting the speed characteristics of the steam turbine.

On account of its uniform rotative velocity and its relatively large fly-wheel capacity, the turbo-generator is particularly suitable for operating rotary converter systems such as the Interborough. Such machines also operate extremely well in parallel, and the operation of a steam-turbine unit with a reciprocating unit is, in general, considerably better than reciprocating units with each other, due to the fact that the mean rotative velocity of the combined units is better than in the case of reciprocating units alone. In the case of the Interborough slow-speed generators, this effect is not noticeable, as there is no evidence of periodic speed fluctuations in the slow-speed units, due to a large extent, to the heavy dampers on the machines, their large fly-wheel capacity, and the proportions of the engines which are designed for very small angular variation.

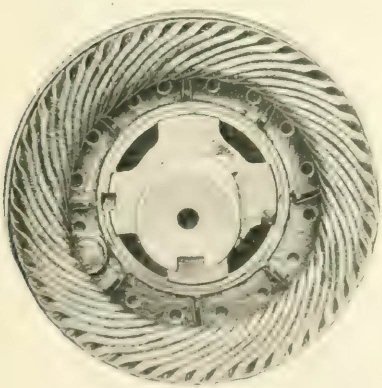
Some months ago a series of tests was made to determine the paralleling qualities of turbo-generator units. At full voltage the machines ran perfectly in parallel. Fluctuations in speed were so slight that periods from one to fifteen seconds could be obtained for synchronizing. When the voltage was reduced to 60 per cent. of the normal, the machines would carry the full current without any evidence of hunting. The voltage was further reduced and tests were made, until about 15 percent. of the rated voltage was obtained. Under these conditions the machines still remained in parallel when carrying full-load current, but the conditions of

paralleling were not perfectly stable, the load being transferred from one machine to the other at an irregular but not rapid rate. As the synchronizing power varies approximately as the square of the voltage, it was extremely low in the last test cited. It is evident, therefore, that but small interaction is required between such machines to maintain parallel operation.

ARMATURE WINDING FOR CONSTANT POTENTIAL DIRECT-CURRENT MACHINERY

THERE are two general types of armature windings, the open-coil and the closed-coil. The former is used only on series constant-current machines. The latter is used on all constant voltage direct-current generators and motors and on some types of alternating-current machines.

From the name closed-coil or closed-circuit it is rightly inferred that all the wire on the armature, if removed and uncoiled, would form one or more closed loops. If a winding thus considered forms a single closed loop, there must be at least two paths through the armature, the current dividing at *A* and uniting at *B*, Fig. 1. A closed-coil armature can then have no fewer than two paths in parallel, in which case the voltage of the machine will be the voltage between *A* and *B* and will be that voltage which is generated by one-half of the total number of conductors in the armature slots. The voltage generated by the other half is in parallel with that of the first half. The result is much the same as two independent sources of electromotive force in parallel. There may be more than two parallel paths through the armature winding even when all the wire on the armature forms but a single closed loop, as will be seen later. There will, of course,



REAR END OF ARMATURE

be more than two parallel paths if the winding forms more than one closed loop, but such windings are not found on commercial machines and will therefore not be considered.

Consider an armature having twelve slots and four wires per slot. Also consider that all end connections are removed, leaving 48 free ends of wire at each end of the armature. As the armature revolves each wire will have an electromotive force generated in it. If the rotation is clockwise the directions of the generated electromotive force in the wires moving under the north poles will be down and under the south poles will be up, as shown in Fig. 2. In connecting up these armature wires to form an armature winding three different things must be considered: first, the conductors that are to form one of the two or more parallel paths must be connected in series so that the individual electromotive forces at any instant will add; second, all the so-formed series paths must be connected in series so that their voltages oppose each other, and third, this arrangement must be symmetrically arranged so that the rotation of the armature will not affect the armature circuits in their relation to the poles.

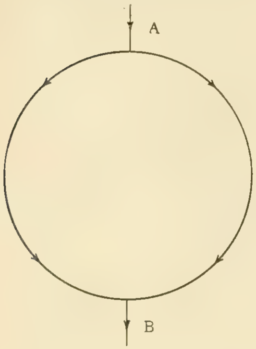


Fig. 1.

Armature windings may be divided into two classes, ring winding and drum winding. The former represents a winding, every turn of which passes through the armature spider. This form was first used owing to its extreme simplicity, but has long since been abandoned on account of the large amount of wire required. It is obvious that the wires passing through the armature spider, as shown in Fig. 3, have no electromotive force generated in them. The ring-wound armature is a thing of the past. It is never used on modern machines and is of historic interest only.

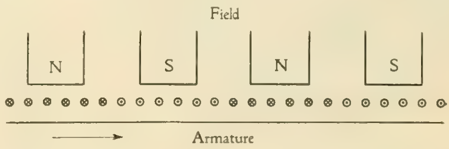


Fig. 2—The relative position of the conductors on the armature and the field of a generator

The drum winding is used on all dynamo machinery. It may appear in a great variety of forms, two of which are by far the most common and are described below.

Drum Winding.—In Fig. 3 consider all the connecting wires to be removed, leaving only the 48 radial lines representing the 48 conductors. The larger circle will represent the rear of the armature and the smaller circle the front of the armature. Starting with the front end of the slot *C*, the wires pass out the rear and must there be connected to some set of wires whose arrows are pointing forward. The rear ends of *C* must then be connected with those of *E, J, D, H*, or *L*. *C* and *D* connected will give the maximum electromotive force, since those two coils simultaneously occupy maximum cutting positions, but this arrangement will not permit of a symmetrical winding, neither will *C* to *L* or *C* to *E*. *C* to *H* or *C* to *J* will, however, wind symmetrically. Now in Fig. 3 connect the wires in the slots *C* and *H*, such that they form one continuous coil of four turns, Fig. 4. From *H* carry the last wire to a commutator bar, then to

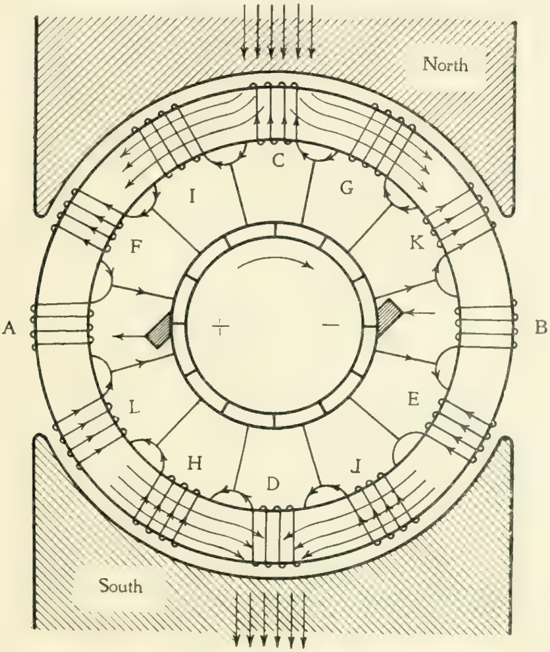
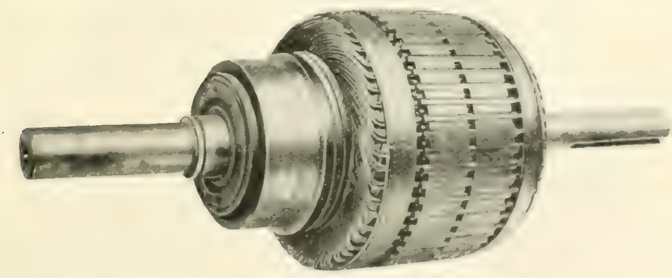


Fig. 3—Ring-wound armature. 12 coils, four turns per coil. 48 conductors. 12 commutator bars


Armature for a 15-HP., four-pole, direct-current motor

K and wind slots *K* and *A,* then *E* and *I,* etc. Since each coil occupies two slots in Fig. 4, if there is but one commutator-bar per coil, as shown, there will be but half as many bars as shown in Fig 3.

In a drum winding the greater part of the problem is a geometrical one. Fig. 3 could not be drum wound as shown in Fig. 4 if the armature had thirteen slots.

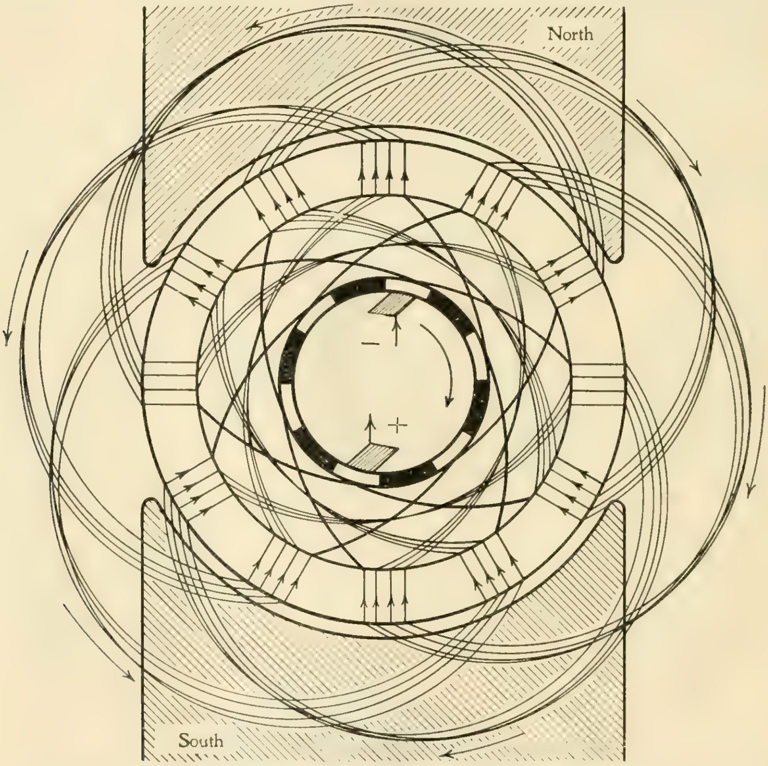


FIG. 4—SAME MACHINE AS SHOWN IN FIG. 3, DRUM-WOUND. 48 CONDUCTORS, SIX COILS, FOUR TURNS PER COIL, SIX COMMUTATOR BARS.

Drum Winding for Multipolar Machines.—All drum windings for the armatures of multipolar machines are divided into two general classes: First, lap-wound, a development of which is shown in Fig. 5. Second, wave-wound, similarly shown in Fig. 6. These winding are sometimes referred to as multiple and series-windings, respectively. Their true distinction, however, lies in the

fact that in the first case the turns of wire lap back each turn, while in the other case each turn progresses from pole to pole. The conductors under each pole have a definite direction with reference to their generated electromotive force, and the first point of consideration is to connect the conductors so that the electromotive forces add. An inspection of the various diagrams will quickly show that if the electromotive force be followed down a wire which at any instant is under a north pole, that wire must be connected to one under a south pole. From an electrical point of view, this need not be the next adjacent pole. It may be any south pole of the field. For reasons of a geometrical nature, however, and because it will require a minimum length of wire, the conductors lying under adjacent poles are connected together, and as far as possible those lying under similar portions of the poles will be joined since this procedure will obviously yield a greater electromotive force.

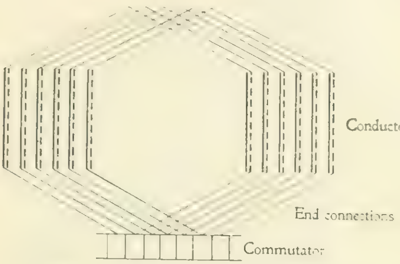


FIG. 5—LAP WINDING. THE DOTTED CONDUCTOR BARS ARE IN THE BOTTOMS OF THE SLOTS; THOSE SHOWN SOLID ARE IN THE TOPS OF THE SLOTS

The distance between the centers of two adjacent poles is the pole pitch and the distance between the two conductors of the same

FIG. 6—WAVE WINDING. THE DOTTED CONDUCTOR BARS ARE IN THE BOTTOMS OF THE SLOTS; THOSE SHOWN SOLID ARE IN THE TOPS OF THE SLOTS

coil is the throw of the coil. These are usually expressed in terms of armature slots instead of degrees or inches.

In lap windings the throw of the armature coils can never equal the throw of the end connections. It is usually made one more or one less. In wave windings these throws may be equal, but are not

necessarily so. That is, the number of slots enclosed by a coil is not necessarily equal to the number of slots lying between this coil and the coil to which it is connected at the commutator. For instance, in Fig. 11, one coil lies in slots 1 and 9, the next coil connected in series with this coil, lies in lots 17 and 25. If the throw had been made 1 and 8, the first coil would lie in slots 1 and 8, and the second in slots 17 and 24. In this arrangement, while the throw of the coil is 1 and 8, the throw of the end connections is 1 and 10. In any case, however, the throw of the coil, plus the throw of the end connection, must very closely equal two times the pole pitch. In practice it is customary to make the throw of the coil equal to or

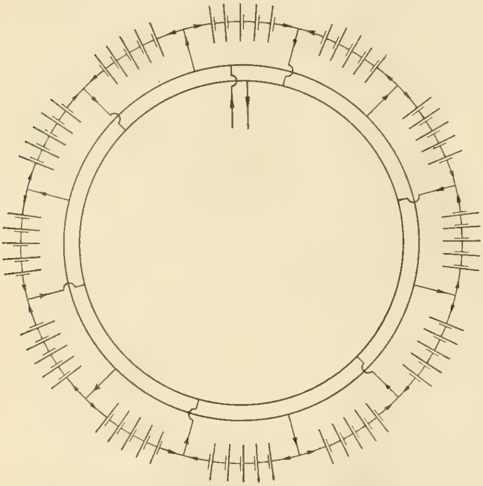
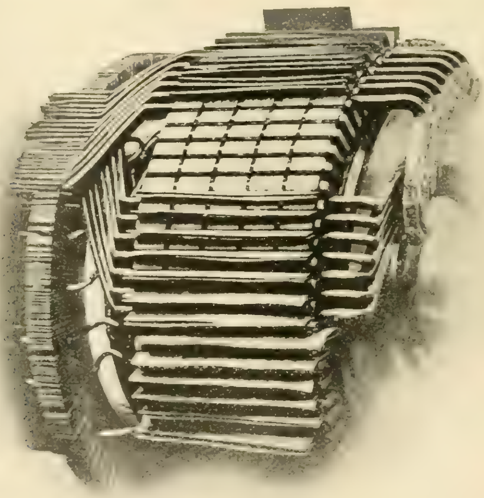
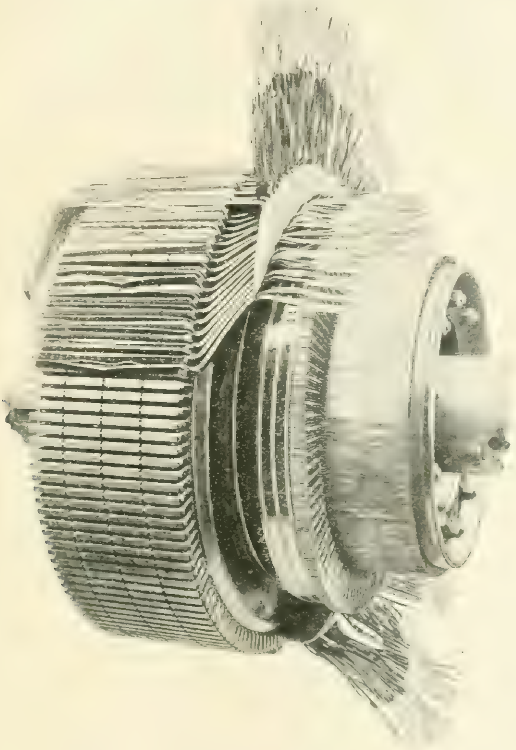


FIG. 7—AN ARRANGEMENT OF CHEMICAL CELLS IN SERIES GIVING A PARALLEL CONNECTION AT THE TERMINALS ANALOGOUS TO A LAP-WOUND ARMATURE



DIRECT-CURRENT ARMATURE. LAP WOUND. TWO COILS PER SLOT

slightly less than the throw of the end connection. When a coil is composed of several turns, it is obvious that this construction requires less wire than if the throw of the coil were slightly greater than the throw of the end connection.



DIRECT-CURRENT ARMATURE. EITHER LAP OR WAVE WOUND. TWO COILS PER SLOT

If the throw of the coils is very much less than the pitch it is quite obvious that there will be periods when both the conductors of one coil will lie under the influence of one pole which, of course, would mean periods of zero electromotive force in that coil. The throw is therefore usually made but slightly less than the pitch since this requires less wire, and also because it quite often happens that a throw exactly equal to the pole pitch would encounter a fraction of a slot, or for various other geometrical reasons. The remainder of the problem of winding an armature is one of geometry. All armatures are wound for one or two condi-

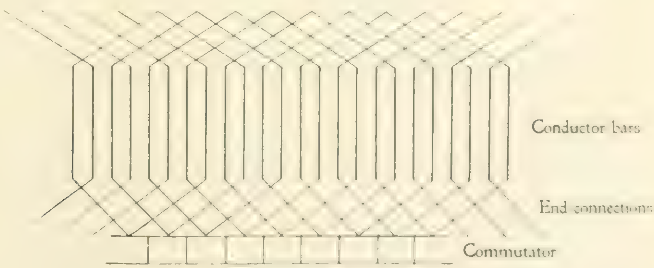


FIG. 8—LAP WINDING, ONE COIL PER SLOT. IT IS NECESSARY THAT EACH COIL OCCUPY AN ODD AND AN EVEN SLOT

tions, viz., low voltage and large current, or high voltage and low current. For the first condition the armature must be provided with a large number of paths in parallel, and for the second a very small number of parallel paths with a correspondingly large number of series conductors. Commercially this is accomplished by two types of winding: first, the lap winding having a commutator pitch of adjacent commutator bars and therefore hav-

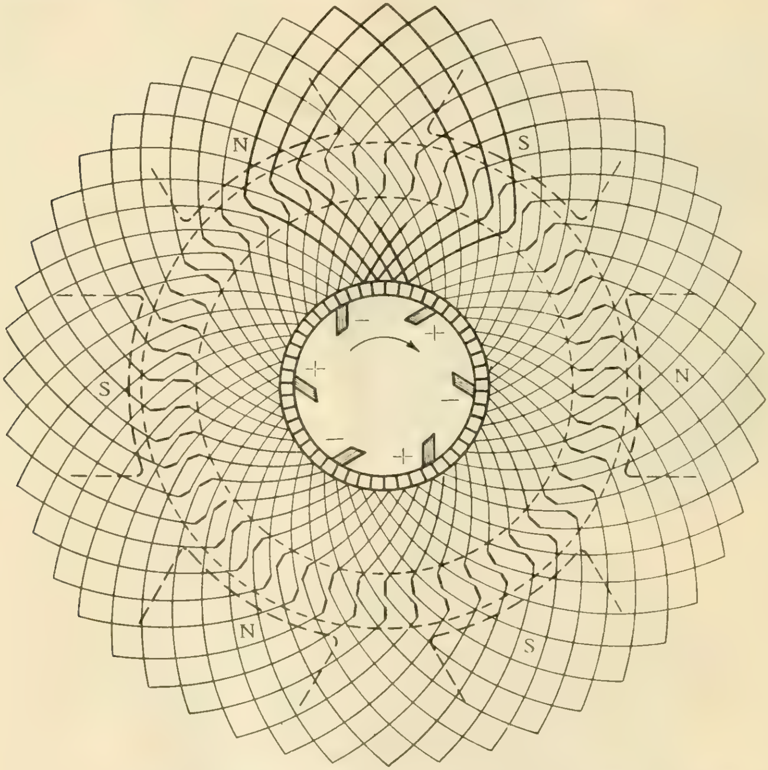


FIG. 9—LAP WINDING. MULTIPLE CIRCUIT, PROGRESSIVE, SIX POLES, 47 SLOTS. 47 COMMUTATOR BARS, 47 ARMATURE COILS, ONE TURN PER COIL, TWO COILS PER SLOT

ing parallel paths equal to the number of poles; second, the two-circuit wave winding having two parallel paths. These two types will be more especially discussed. Some others are merely mentioned as possible constructions.

Lap Winding.—The following refers to lap windings having as many paths in parallel as there are poles, though there may be

two, three, four, or more times this number. In these other cases wide brushes are necessary, which give troublesome contacts.

Each pole represents in a way a complete generator in itself. There is always a brush for each pole and all the brushes of like sign are joined to form the two terminals of the machine as shown in Fig. 7, where the conductors lying under each pole of a four-pole machine are represented by four cells of battery.

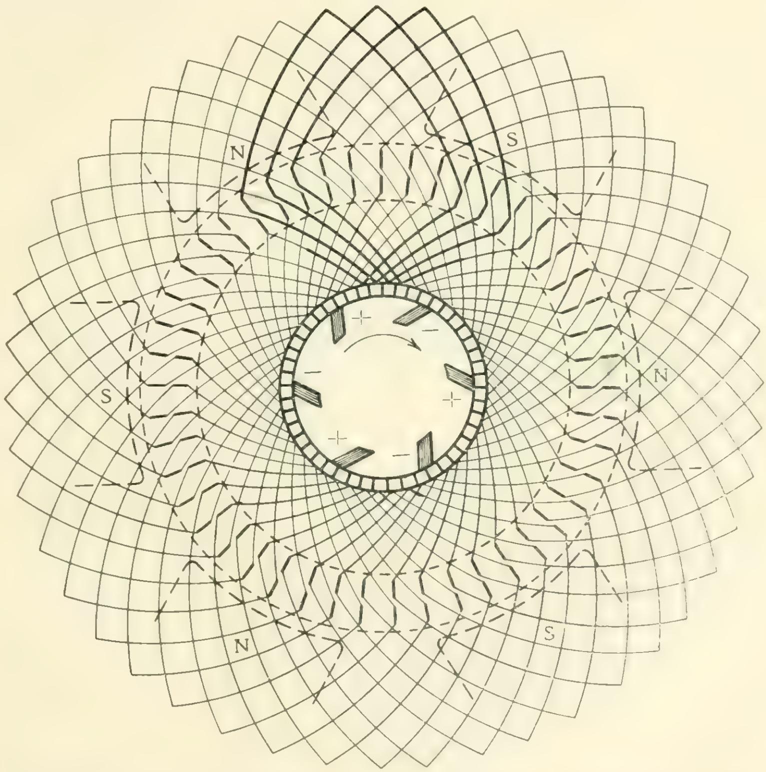


FIG. 10—LAP WINDING, MULTIPLE CIRCUIT, RETROGRESSIVE, SIX POLES, 47 SLOTS, 47 COMMUTATOR BARS, 47 ARMATURE COILS, ONE TURN PER COIL, TWO COILS PER SLOT

If each slot accommodates two coils, i. e., one side each of two coils as shown in Fig. 5, this winding may be constructed on an armature of any number of slots, but if each slot holds but one conductor, as shown in Fig. 8, the number of slots must be even. For if any armature be constructed with two conductors per slot, as shown in Fig. 9 and succeeding diagrams, then to change it

to one conductor per slot would mean to provide twice as many slots, and whether the armature in the first place had an odd or an even number of slots, twice the number would always be an even number.

Figs. 9 and 10 show standard lap windings for a six-pole machine. In each case the coils are considered as being wound clockwise. In one instance the general progression around the

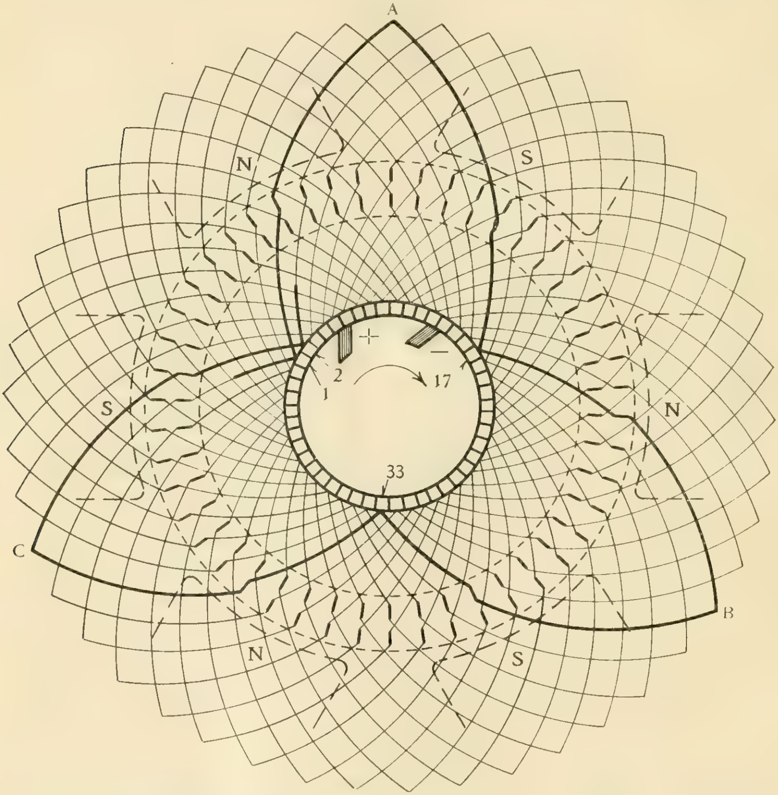


FIG. 11—WAVE WINDING. TWO-CIRCUIT, PROGRESSIVE, SIX POLES, 47 SLOTS, 47 COMMUTATOR BARS, 47 ARMATURE COILS, ONE TURN PER COIL, TWO COILS PER SLOT

armature is clockwise and in the other, counter clockwise. This results from the throw on the commutator end. The commutator contains 47 bars. Starting at bar No. 1 the progression is forward or backward, depending upon whether the end of the first coil and the beginning of the second coil is connected to bar No. 2 or No. 47. Hence the obvious names, progressive and retrogres-

sive. At any instant there are six slots whose wires have a zero electromotive force. Therefore the commutator bars connected to these conductors will mark the approximate location of the brushes.

There is practically no difference between the progressive and the retrogressive lap winding. They produce the same electromotive force, commutate equally well, and an armature of any number of slots can be wound either way from a geometrical con-

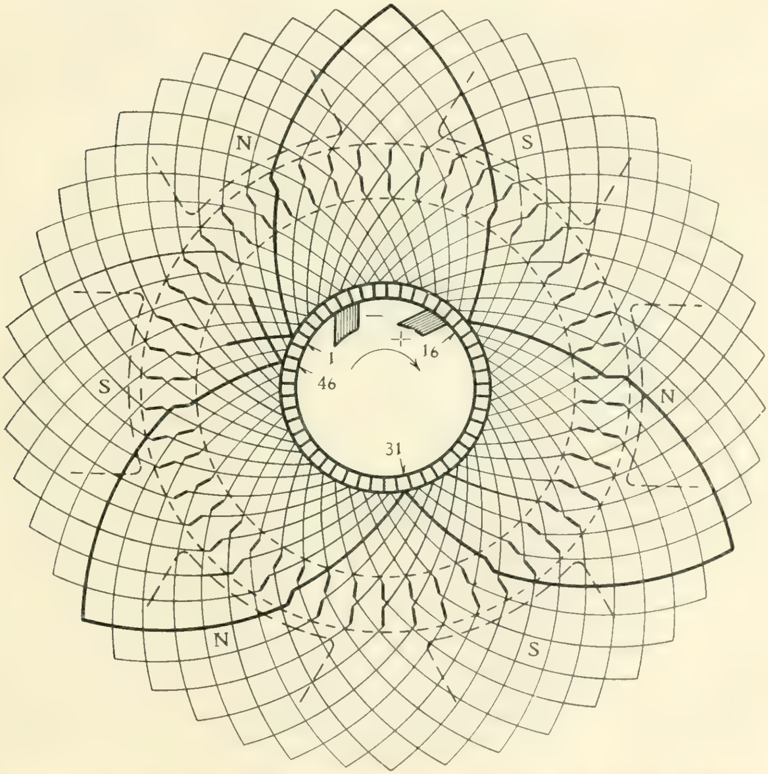


FIG. 12—WAVE WINDING. FOUR CIRCUITS, RETROGRESSIVE, SIX POLES, 47 SLOTS, 47 COMMUTATOR BARS, 47 ARMATURE COILS, ONE TURN PER COIL, TWO COILS PER SLOT

sideration. Other things remaining unchanged, the direction of rotation is reversed in the two cases, since the current through the armature is reversed. Possibly the retrogressive winding will require a trifle more wire. Lap windings on machines built by the Electric Company are always wound progressively. This is more for a uniformity of standardization than for any other reason.

WAVE WINDING.—A wave winding is often called a series or two-circuit winding, which as a rule it is, though not necessarily. There are usually two paths in parallel through such a winding regardless of the number of poles. The general form of the winding is shown in Figs. 11, 12, 13 and 14. The heavy lines indicate the series connection of the conductors. The throw of the coils must, of course, be a fixed value. The pitch on the com-

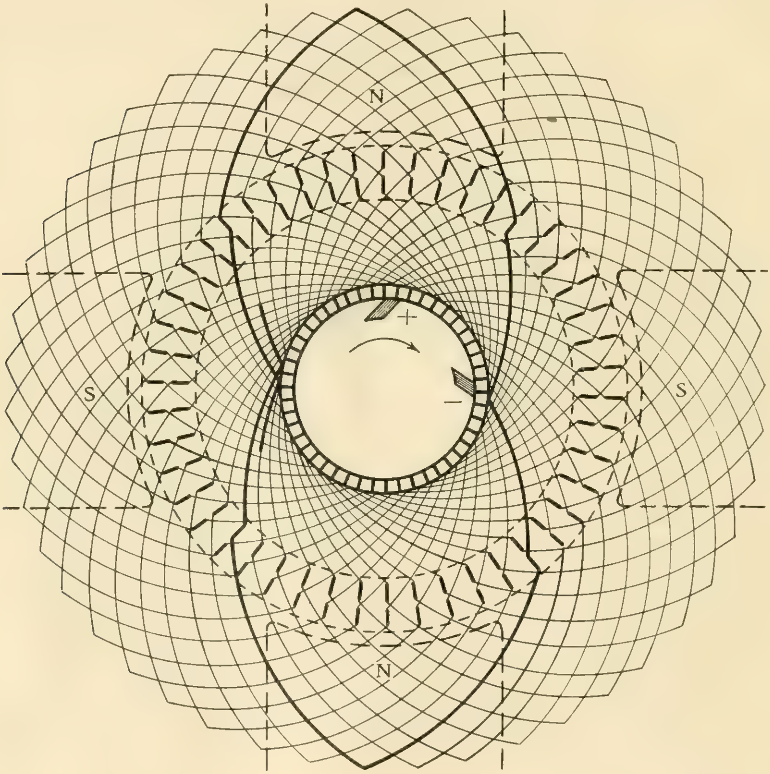


FIG. 13—WAVE WINDING. TWO-CIRCUIT, PROGRESSIVE, FOUR POLES, 47 SLOTS, 47 COMMUTATOR BARS, 47 ARMATURE COILS, ONE TURN PER COIL, TWO COILS PER SLOT

mutator must also be constant since the finished winding is to be perfectly symmetrical. Following the heavy line from bar No. 1, we pass through coils *A*, *B* and *C*, touching the commutator at bars 17, 32 and 2. That is, with a commutator pitch of 1 and 17, the second round will start with bar No. 2, the third with bar No. 3, etc. The brushes are located as described for lap windings. In

Fig. 11 only two brushes are shown. Starting with the positive brush, follow through the winding clockwise. When the negative brush is reached it will be noted that one-half of all the coils on the armature have been passed over. The same procedure counter-clockwise will take the other half of the conductors. This winding is then two-circuit and the two brushes are quite sufficient, any two, one plus and one minus, will do. The addition of the

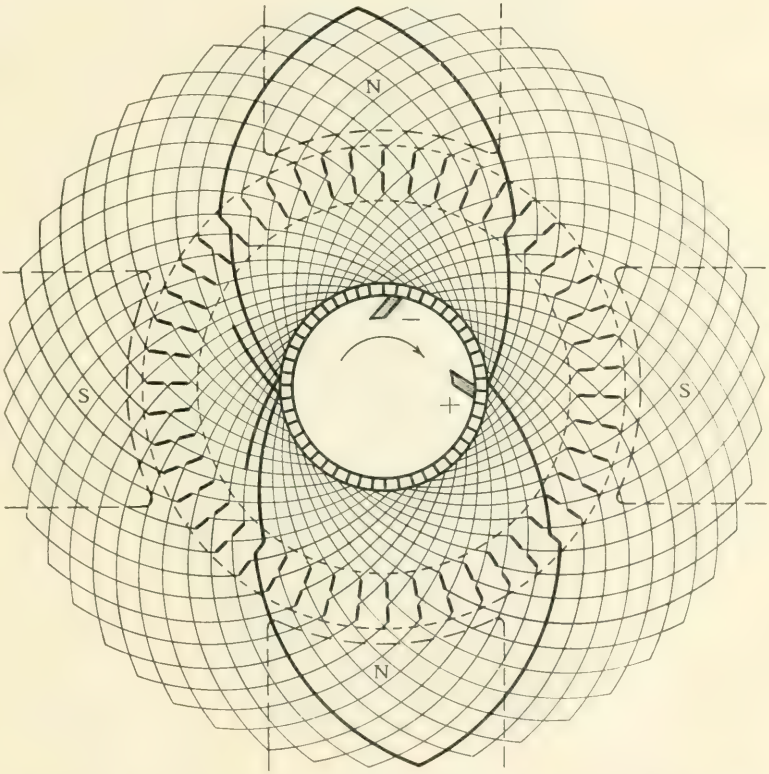


FIG. 14—WAVE WINDING. TWO CIRCUIT, RETROGRESSIVE, FOUR POLES, 47 SLOTS, 47 COMMUTATOR BARS, 47 ARMATURE COILS, ONE TURN PER COIL, TWO COILS PER SLOT

other four brushes would practically amount to increasing the size of the ones shown since three brushes of like sign would be only one coil apart. If all the wire were removed from this armature and opened out the location of the brushes would be as shown in Fig. 15. When the line current becomes too large for a given size of brush, the other brushes may be added simply

as an easy means of increasing the area of brush contact, without increasing the length of the commutator. Fig. 11 shows a progressive winding for the same reason as explained in the case of lap-wound machines. It may also be wound retrogressively, as shown in Fig. 12. With a commutator pitch of 1 and 16, once around the commutator engages bars 1, 16, 31, 46, the second round starting at 46, which is two bars back of 1. Beginning with

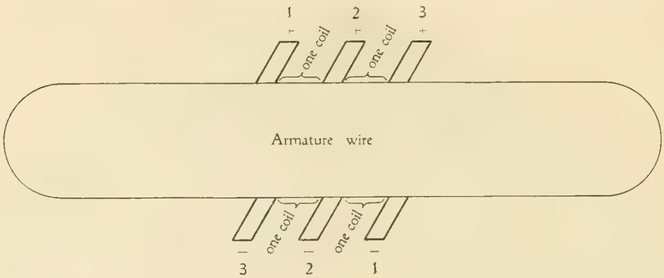


FIG. 15—DIAGRAM REPRESENTING THE WINDING OF FIG. 11 REMOVED FROM THE ARMATURE

the positive brush and following through the winding clockwise to the negative brush, only one-fourth of the winding will be passed over. The winding is therefore four-circuit or two-circuit double wound. For, beginning with the two wires leading clockwise from bars 1 and 47, they follow around the armature in parallel and end at bars 46 and 45, respectively. The second round

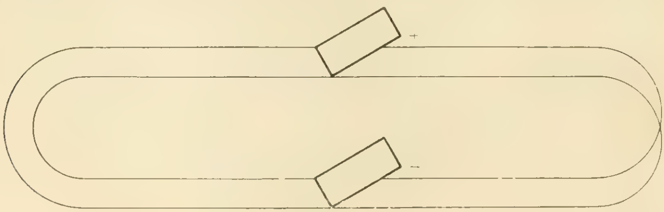


FIG. 16—DIAGRAM REPRESENTING THE WINDING OF FIG. 12 REMOVED FROM THE ARMATURE

ends with 44 and 43, which, taken as a unit, is adjacent to 46 and 45. The brushes must be wide enough to cover two segments and thus collect current from each circuit. This is a source of considerable trouble, since it is difficult to maintain a good reliable brush contact with wide brushes covering two or more segments. For this reason this particular form of wave winding is not used.

Fig. 16 shows the arrangement, wire removed. Obviously, the total voltage generated by this winding will be one-half that generated by the one shown in Fig. 11, and the current capacity of the armature will be twice as great.

Whether a wave winding is made retrogressive or progressive depends upon the geometrical solution. With six poles and

DIRECT CURRENT ARMATURE FOR 600 KW., 12 POLE GENERATOR. LAP WOUND

47 slots the winding can only be two-circuit when wound progressively. Had there been 49 slots the winding would have been two-circuit retrogressive with the same pitch on the commutator. For all wave windings the number of slots on the armature for any given machine are made some convenient multiple of the number of poles, plus or minus one. This will give either

a retrogressive or a progressive two-circuit solution for any number of poles.

Practically, all wave windings are wound two-circuit. To accomplish this the only geometrical requisite is that the first time

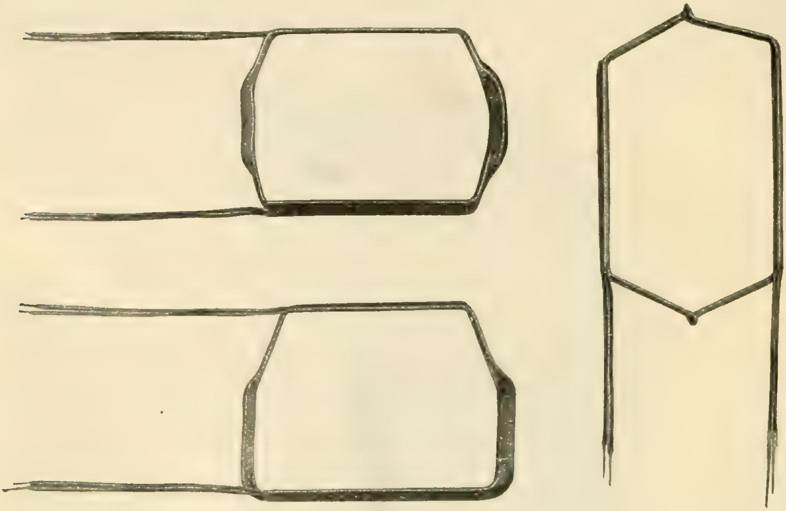
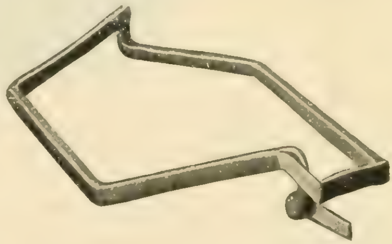


FIG. 17—DIRECT-CURRENT ARMATURE COILS SHOWING DIFFERENT FORMS OF END CONNECTIONS WHICH ARE OCCASIONED BY DIFFERENT MECHANICAL CONSIDERATIONS. THESE COILS MAY BE CONNECTED EITHER LAP OR WAVE

around the commutator the wire ends on a bar adjacent to the bar of starting, either forward or backward. The number of slots, coils per slot, and poles will very quickly determine the geometrical construction. Certain combinations require the omission of one commutator bar. Others require the omission of one coil. Sometimes a coil and a bar are both omitted and some combinations cannot be wound at all. It is interesting to note that whether a winding is lap or wave depends in no wise upon the throw of the coils, but upon the connection of the wires to the commutator. The ordinary formed coils shown in Fig. 17 may be fitted to an armature which may be then connected either lap or wave. If it is to be lap connected,



ARMATURE COIL FOR LAP WINDING ONLY

it may be either retrogressive or progressive, but if it is to be wave connected the problem is at once limited by the geometrical construction. Figs. 9 to 14, inclusive, are constructed upon the same armature data and afford a good comparative study. With the exception of Fig. 12 they all represent standard windings. It will be noted that a change from progressive to retrogressive winding reverses the polarity of the terminals if a generator, and the direction of rotation if a motor. It sometimes happens that such an armature is to be wound with four coils per slot, as shown in Fig. 18. This means that there will be twice as many commutator bars as there are slots, which will of course result in an even number of bars. In which case it may be necessary to omit one bar and one coil. Such omitted parts are referred to as idle. This is, however a geometrical problem. As a rule the geometrical arrangement can best be worked out by constructing an actual diagram or arranging a table of slot numbers rather than by formulae calculations.

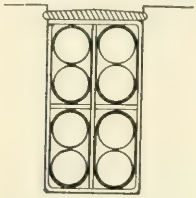


FIG. 18—ARMATURE SLOT SHOWING TWO TURNS PER COIL, FOUR COILS PER SLOT.

THE INDUCTION MOTOR AND THE ROTARY CONVERTER AND THEIR RELATION TO THE TRANSMISSION SYSTEM*

By CHAS. F. SCOTT

TWO important functions of an alternating-current transmission system are the production of mechanical power and the furnishing of direct current.

The induction motor and the rotary converter have become the usual means of transforming energy into these forms. The wide extent to which they are now used is a notable feature of recent electrical progress. An examination of their behavior in service, especially in connection with other apparatus which might be used for the same purposes, will indicate the particular characteristics which have made them so successful. Occasion will be taken also to note some of the important inter-relations between the various kinds of receiving apparatus and the transmission circuit and the generators by which they are supplied with current.

I.—THE INDUCTION MOTOR.

Power may be produced by the synchronous motor or by the induction motor. A comparison between the two motors may be made by placing in parallel columns their respective characteristics in service, i. e., those which concern the operation rather than the design. An induction motor with a secondary of the "squirrel cage" type, started by applying a low E.M.F. to the primary, is taken for comparison—the description will require modification in some particulars if the secondary circuit is provided with adjustable resistance. These are of minor importance and do not affect the general comparison.

SYNCHRONOUS MOTOR.	INDUCTION MOTOR.
AUXILIARY APPARATUS.	
1. A starting motor; or, if self-starting, some form of resistance or transformer for reducing the voltage.	1. A two-way main switch with auto transformers giving a low E. M. F. for starting. This may be located at any distance from the motor.
2. An exciter, driven by the motor or otherwise, with circuits to switchboard and motor.	2. No exciter is required.

* A paper presented at the 18th Annual Meeting of the American Institute of Electrical Engineers, Buffalo, August 22d, 1901.

SYNCHRONOUS MOTOR.	INDUCTION MOTOR.
3. Rheostats for exciter and motor.	3. No field rheostats are required.
4. Instruments for indicating when field current is properly adjusted.	4. No instruments are required.
5. Main switch and exciter switches.	5. No exciter switches are required.
6. A friction clutch is required in many cases.	6. No friction clutch is required, as the motor starts its load.
CONSTRUCTION.	
1. Armature winding.	1. Primary winding.
2. Field winding with many turns. Liable to accident from "field discharge" if exciting current is suddenly broken; or from high E. M. F. by induction from the armature if the field circuit is open.	2. Secondary, short circuited.
3. Collector rings and brushes.	3. No moving contacts on "squirrel cage" secondary.
STARTING—NORMAL.	
1. Motor is brought up to speed without load; if starting motor is used, the main motor must be brought to proper speed and "synchronized;" if self-starting, the starting devices must be cut out of circuit at the proper time.	1. Throw switch to starting and then to running position.
2. Exciter is made ready for delivering proper current and the motor field must be excited, adjustments being made by rheostats until instruments give proper indication.	2. There is no exciter. (The motor is magnetized by lagging current from the generator.)
3. Load is thrown on by friction clutch or other means.	3. The motor starts its own load.
STARTING—ABNORMAL.	
1. If the several operations in starting be performed improperly or in wrong order, injury may result. If a starting motor is used, the synchronizing may be attempted at an improper speed or phase; if the motor is self-starting and it is connected to the circuit without the starting devices, a large current will flow which may induce a high E. M. F. in the field circuit; if the field circuit be open, a high E. M. F. may be induced in it at other times also.	1. The only possible error is in starting with the switch in the running or full voltage position, which simply causes the motor to exert a greater torque and consume a greater current than is necessary.
2. If a load having inertia be applied by closing the friction clutch too quickly the motor may be overloaded and stopped.	2. The motor starts its own load and requires no friction clutch.
3. If motor stops owing to failure of current supply, it is not self-starting when the current returns. An attendant is always required for starting.	3. The motor will stop if the current is cut off at the power house and then start again when the current is supplied to the circuit.

SYNCHRONOUS MOTOR.	INDUCTION MOTOR.
STARTING AND MAXIMUM RUNNING TORQUE.	
1. The starting torque of the self-starting motor is very small and an excessive current is required for developing it. The motor starts as an induction motor, but inefficiently, as the design which is best for synchronous running is not good for starting.	1. The starting torque is adjustable and may be several times full load torque.
2. The maximum torque is several times the full load torque, and occurs at synchronous speed; below this speed the torque is very small; any condition which momentarily lowers the speed causes the motor to stop.	2. The maximum torque is usually greater than that of the synchronous motor, but it occurs at a reduced speed and there is a large torque at lower speeds.
SPEED.	
1. The motor has a single definite speed; at other speeds its torque is very small and the current is very large.	1. The motor may be designed for a practically constant speed, with large torque at lower speeds; or for several definite speeds by changing the number of poles; or for variable speed work, such as is required for cranes, elevators, hoists and the like.
CURRENT.	
1. If there is useful starting torque the current required for producing it is very great.	1. The starting current may be made proportional to the torque, and is 1½ to 2½ times that required for the same torque at high speed.
2. The running current depends upon the wave form. If the wave form of the motor and of the circuit differs, a corrective current will follow, which cannot be eliminated by adjustment of field excitation.	2. The running current is practically independent of the difference in wave form, as it has no wave form of its own.
3. The running current depends upon uniformity of alternations of the current, *i. e.*, upon the uniformity of the speed of the generator and other synchronous motors. The motors attempt to follow the generator speed exactly. If the latter pulsates, the motors pulsate also; they vibrate about a mean position. "hunting" or "pumping." One motor pumping incites others. The current is increased even though the conditions may still be operative.	3. The current is practically independent of fluctuations in generator speed, as there is a slip between the synchronous and the actual speed of the motor.
4. The running current depends upon the relation between the field current (which is adjusted by the attendant) and the E. M. F. of the circuit. The main current may be made leading or lagging or theoretically it may be neither. The E. M. F. of the circuit is an element which is under the partial control of the attendants at every motor as well as at the generator station.	4. The current is not subject to any adjustments which the motor attendant can make, nor is the E. M. F. of the circuit in any way under his control.

SYNCHRONOUS MOTOR.	INDUCTION MOTOR
POWER FACTOR.	
1. As the power factor is the relation between actual current and energy-current, it is dependent upon wave form, hunting and field current. Under favorable conditions the motor may have a high power factor; under many actual conditions it may not; under some conditions the highest attainable power factor is less than that of the induction motor.	1. The power factor varies with load, but is definite and is practically independent of wave form and hunting.
2. The current may be lagging or leading, depending upon the motor field strength.	2. The current to the motor is always a lagging current.
REACTION UPON GENERATOR AND CIRCUIT.	
1. The motor impresses its own wave form on the circuit.	1. The motor has no wave form to impress upon the circuit; its tendency is to smooth out irregularities in a wave which is not a sine wave.
2. A motor may augment the fluctuations in generator speed by the oscillation of its own armature. One motor may increase the disturbance in the circuit so as to interfere with other motors which would not have been seriously affected.	2. The motor has a damping action upon fluctuations in frequency; in some cases a synchronous motor which hunts may run smoothly when an induction motor is connected to the same circuit.
3 As the current may be either lagging or leading, the drop in E. M. F. in the generator and between generator and motor may be either more or less than that which could be caused by a non-inductive load or by an induction motor.	3. The drop in E. M. F. is always greater than would be caused by non-inductive load.
4. If a short circuit occurs in the transmission system the motor acts as a generator, which thereby greatly increases the current and the intensity of the short-circuit.	4. The motor does not generate current when there is a short circuit.
5. If the circuit is opened, either by a switch, a circuit breaker, a fuse or the breaking of the line, the motor speed falls, its E. M. F. is no longer in phase with that of the circuit; the two are thereby added, thus doubling the normal E. M. F. and bringing increased strains on the insulation and the opening devices.	5. The motor does not generate E. M. F. when it is disconnected from the circuit.
CAUSES WHICH MAY ACCIDENTALLY STOP A MOTOR.	
1. Momentary lowering of E. M. F. caused by short circuit on the line, or by accident at another motor, or by error in synchronizing a generator, or by the "switching over" of the motor from one circuit to another, is apt to cause the motor, particularly if carrying load, to fall from synchronism and come to rest.	1. Momentary lowering of E. M. F. causes momentary decrease in speed.

SYNCHRONOUS MOTOR.	INDUCTION MOTOR.
2. A heavy load, even momentary, may exceed the limiting torque and cause the motor to drop from synchronism, even though the load be removed immediately. The connection between generator and motor is rigid.	2. An excessive load receives the stored energy of the motor and of the load itself as the motor falls; when the excess load is removed the motor speed increases again. The connection between generator and motor is elastic.
3. If the generator speed suddenly increases, a motor carrying a load having inertia may be unable to increase its speed quickly without exceeding the limiting torque, which will cause the motor to stop.	3. The motor readily follows changes in generator speed.

SUMMARY.

1. The motor is an *active* element in the system; it acts as a generator in impressing its own wave form, its E. M. F. and its fluctuations upon the circuit. These fluctuations may be caused by an intermittent load.	1. The motor is a *passive* element in the system. Each motor attends to its own work and does not try to run the system.
2. The motor is a sensitive element in the system. Its successful operation is dependent upon a proper relation between the design of the motor itself and of other machines connected with the system. Its successful operation also depends upon the proper adjustment and freedom from speed fluctuation in generators and other motors. It is liable to momentary variations from normal conditions, such as a sudden overload and sudden increase of generator speed or a momentary fall in E. M. F.	2. The motor is not sensitive to differences in the design of other apparatus operating on the same system.
3. The motor requires skill and care on the part of the attendant for starting, for readjusting and for keeping the various brushes and auxiliary apparatus in proper condition.	3. No experience and electrical skill are required of the attendant and there is little or nothing to get out of order either through carelessness or design.
4. The proper factor is under the control of the operator and the current may be made leading or lagging. Instruments are necessary, in order that proper adjustments may be made by the attendant.	4. The motor has a definite power factor, depending upon the load; the out-of-phase current does not vary greatly at different loads. The changing load, therefore, has comparatively little effect upon the drop in voltage and in regular service there is little liability that the motor will disturb the E. M. F. of the circuit.
5. The motor and its operation are complex and involve many possibilities of accident.	5. The motor and its operation are simple and reliable.

The synchronous motor is obviously not suitable for general distribution of power, owing particularly to its lack of starting torque, the skill required in attendance and the liability of the motor to stop if the conditions became abnormal. These objectionable

features, however, are of much less importance when motors are installed in sub-stations or are of sufficiently large size to justify an attendant.

The characteristic of the synchronous motor which may be particularly advantageous is the fact that the power factor of the current can be varied and that the current may be made leading. In this way the current required and the drop in the generator and transmission circuit may be reduced. If the motor is used on a circuit supplying induction motors the synchronous motor may be given a leading current, thus neutralizing the lagging current to other motors. The extra current taken by the synchronous motor for this compensation necessitates a larger size than would otherwise be required.

The characteristic of the induction motor which is usually regarded as most unfavorable in comparison with the synchronous motor, is the fact that its current is always a lagging current. In a comparison with synchronous motors only large sizes should be included, as synchronous motors of small size are not to be seriously considered in practical work. The induction motors of large size have relatively high power factors, i. e., the out-of-phase current is small. Moreover, this current is definite in kind and nearly constant for different loads, so that it is a definite and constant element which may be provided for. It may therefore create less disturbance on the system than the out-of-phase current of the synchronous motor, which is either lagging or leading, large or small, depending upon the intelligence and care of the attendant and upon other conditions. In one case the voltage of the system is under the control of the attendant in the power house and the lagging current to induction motors which are running with either constant or varying load is practically constant. On the other hand, when synchronous motors are used, the voltage of the system is dependent upon all the motors, and uncertain or disastrous results are liable to be caused by adjustments by the various motor attendants. In many cases it is far better to provide the generators and circuits suitable for supplying the lagging current required by induction motors, rather than to attempt to gain the theoretical advantages attending the use of synchronous motors, as the securing of these advantages requires that so many conditions be favorable. At best the synchronous motor is less satisfactory to operate and is far more sensitive to abnormal or emergency conditions than the induction motor.

The foregoing considerations will indicate why it is that the induction motor has taken such a leading place, while the synchronous motor has been less favored and is now rarely considered seriously as a competitor of the induction motor except in large sizes.

II.—THE ROTARY CONVERTER.

The rotary converter is in its relation to the transmission system essentially a synchronous motor. The foregoing characteristics of the synchronous motor, except those which involve a load upon the motor, apply also to the rotary converter. The starting, however, is somewhat simpler, as there is no load to accelerate except the armature. No separate exciter is necessary, as the converter can furnish its own direct current for exciting. A converter may be compound wound so that as it is loaded the increased excitation changes the out-of-phase current in such a way as to compound the voltage, thus overcoming the drop which would otherwise occur in generator and transmission circuits; whereas, the synchronous motor would cause a falling off in voltage. The rotary converter is generally used in units of considerable size placed in sub-stations having motors.

Direct current is obtained from alternating circuits, either by the rotary converter or a motor-generator, in which either a synchronous or an induction motor is employed.

The rotary converter has the advantage over the motor-generator in point of cost, there being but one machine instead of two; in point of efficiency, there being the loss in one machine instead of two; and in its effect upon the voltage of the transmission system, as it may be compounded to overcome the drop which would otherwise occur in generator and transmission circuit. On the other hand, the E.M.F. of the direct current delivered by the converter depends upon the E.M.F. received; whereas the E.M.F. of a motor-driven generator is independent of the E.M.F. of the supply circuit and may be adjusted or compounded as may be desired. It is found in practice, however, that the voltage delivered by a rotary converter can be satisfactorily adjusted and controlled by regulating devices or by compounding so that usually the close relation between the E.M.F.'s at the two ends of the converter is not disadvantageous, provided the E.M.F. of the supply circuit is reasonably constant. This statement applies to those cases in which a practically constant voltage is desired. There are of course special cases in

which the voltage is to be adjusted over a very wide range or where for other reasons the motor-generator is to be preferred. In many cases the motor may be used either with or without transformers, whereas they would be required with a rotary converter.

A motor-generator employing a synchronous motor does not seem to possess any essential advantage over the converter except in some cases where the independent control of the direct current voltage is desired. The use of the synchronous motor does not remove the objections to the rotary converter which are based on the fact that it is a synchronous machine.

A motor-generator employing an induction motor has the advantage of employing induction instead of synchronous apparatus, thereby securing many of the advantages set forth in the comparison between synchronous and induction motors. Circuits which are supplied by generators in which the speed has a rapid and periodic fluctuation, or in which for any other reason the use of a synchronous machine is impracticable or undesirable, may nevertheless operate an induction motor driving a generator with full satisfaction. The various characteristics of the induction motor under emergency conditions, such as sudden overload, momentary interruption or lowering of the voltage of the supply circuit, may cause little or no inconvenience if the induction motor is used, whereas, it might cause serious interruption to a rotary converter or a synchronously driven generator. The induction motor driving a generator is also to be preferred where units are quite small and the attendance is unskilled. The rotary converter, like the synchronous motor, is unsuited for general distribution in small units.

The foregoing statements and comparisons involving the rotary converter doubtless comprise the principal reasons why this apparatus is being so widely adapted and is in such general use. To indicate the wide use of this apparatus it may be stated that the Westinghouse Electric and Manufacturing Company, with which I am connected, has sold over 400 rotary converters. Of this number 30 percent. are for a frequency of 60 cycles or more. The aggregate output is over 165,000 K.W.*

Most of this apparatus is now installed and is in successful operation. In fact, the difficulties in connection with the installing

*The number of rotary converters Feb. 1, 1905, is approximately 1000, with an output of 500,000 kw.

and operating of rotary converters on circuits which are suited for them are trivial and do not materially differ in amount from those which may be expected to occur in connection with other kinds of apparatus.

The very wide use of the induction motor and the rotary converter is an established fact, and it is believed that many of the reasons for their selection in preference to other kinds of apparatus have been set forth in the foregoing notes.

III.—THE ALTERNATOR

Many of the specific relations between the induction motor and the rotary converter and the supply system have been indicated. There is obviously a close relation between the alternator and the apparatus which it supplies. The conditions are radically different from those involved in incandescent lighting. An alternator which may be quite satisfactory for lighting purposes may be highly inadequate for successfully supplying current for either induction motors or rotary converters.

For supplying current to induction motors an alternator should have good inherent regulation. The lagging current taken by induction motors requires a greater increase in field current for maintaining a given voltage than is required when the load is non-inductive. In order that the field current may not be excessive, the generator should be properly proportioned to have close regulation. The adjustment of the field current by external devices is not a wholly satisfactory substitute for close inherent regulation. Suddenly changing loads or the throwing on or off of motors causes fluctuations in voltage, as the external devices cannot act quickly enough to prevent the disturbance. The necessity of good inherent regulation is all the more necessary where the motors are large in proportion to the size of the generator and where loads are fluctuating.

For the operation of rotary converters the generator speed should be uniform. Engines which are sufficiently uniform in angular velocity to enable generators to run successfully in multiple may nevertheless be unsuited for operating rotary converters or synchronous motors. It is preferable also that generators for operating rotary converters should have good inherent regulation, not only in order that the E.M.F. may be maintained at heavy loads, but also for the purpose of holding the converter rigidly in synchronism. If

the alternating field is comparatively weak, as is usual in poorly regulating machines, there may be a shifting of the magnetic field back and forth with different armature currents, quite similar to the shifting of lead in direct-current machines. It is obvious that if the effective position of the field poles may shift back and forth, this shifting is comparable with fluctuations in generator speed, and becomes a source of unsteadiness in the system which may contribute to the "hunting" of rotary converters. This shifting may occur also in a machine having a strong field if a large proportion of the magnetizing force is absorbed in the iron of the field magnet, i. e., a machine with a saturated field. Such a machine may have good E.M.F. regulation, and still be of an inferior type for the driving of synchronous machinery.

It follows, therefore, that a generator which is to supply induction motors or rotary converters should be selected with reference to the service which it is to supply. In some cases unsatisfactory results have been obtained in the use of motors or converters, duplicates of those which have given full satisfaction elsewhere. The trouble has been located in fluctuating speed or in the characteristics of the alternator supplying the current.

A transmission system must be considered as a unit and the inter-relation between the alternator and the apparatus to which it supplies power must be fully considered.

The theoretical arguments which are occasionally urged against the alternating system, the induction motor and the rotary converter, find their most effective answer in the plants which are now in operation and in their record of service.

The induction motor and the rotary converter to-day represent the survival of the fittest, and confirm the judgment of those engineers who have consistently and persistently advocated their use.

SOME HINTS ABOUT TRANSFORMER OIL

By C. E. SKINNER

FILLING TRANSFORMER CASES WITH OIL

BEFORE filling the case of a transformer with oil, precautions should be taken to see that there is no water in the case and that the transformer itself is dry. It sometimes happens that during the shipment of transformers they are exposed to the weather and that after unpacking it is necessary to transport them for some distance in wagons without covers, giving a chance to collect moisture. Every possible precaution should be taken to prevent moisture entering the cases before they are filled with oil, and care should be taken to remove all air bubbles which may find lodgement in the coils or insulation of the transformer.

Water in Transformers in Service.—It sometimes happens that through faulty bushings or lack of proper precautions in closing up the case when the transformer is installed, water will find its way into the case. This always settles to the bottom of the case, and when in sufficient quantities will rise so as to reach the coils and cause a burn-out. In high-tension transformers the presence of water in the oil is dangerous and may cause burn-outs even though the water does not reach the transformer windings. If water is suspected it may be readily found by inserting a thin glass tube down the side of the transformer to the bottom of the case, the upper end of the tube being stopped by the finger until the tube strikes the bottom. The finger is then removed and the oil allowed to enter the lower end of the tube. The upper end is then closed and the water from the bottom, if any be present, may be drawn out. The contents of the tube should then be discharged into a tall bottle or test tube, and if water is present in any quantity it should at once be apparent to the eye. The remedy in this case is to remove the oil from the transformer and substitute oil which is known to be free from water.

Water and Moisture.—For the purpose of a clearer understanding of the subject we may define water and moisture in oil as follows:

Water is that portion which readily settles out and so becomes at once apparent to the eye when placed in a glass vessel.

Moisture is that portion which is intimately mixed with the oil and which cannot be detected by visual examination. Oil which contains water must also of necessity contain moisture, while oil which is free from water may contain moisture to such an extent as to seriously impair its insulating property.

WATER-COOLED TRANSFORMERS.—Every possible precaution should be taken to see that the cooling coils of water-cooled transformers are tight, but it may happen that during shipment or handling or from other causes the cooling coils are damaged and become leaky. Water, of course, then enters the oil and settles to the bottom. If such transformers are not provided with a gauge glass at the bottom for the observation of water, some of the oil should be drawn from the bottom of the case occasionally and tested for water. The entering ends of cooling coils, which are not covered with oil, should be lagged with tape or some other heat-insulating material to prevent the condensation of moisture on the cold coils in the presence of the warmer air from the heated transformer. This lagging should be kept in good condition.

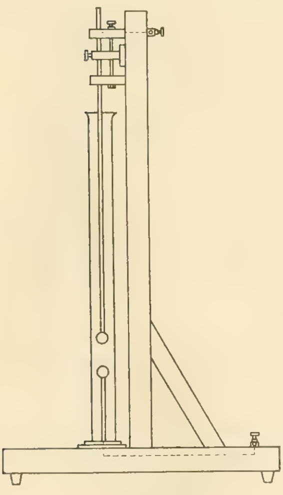
VERY HIGH TENSION TRANSFORMERS.—The foregoing remarks as to precautions to be observed apply to low and medium high-tension transformers. With transformers having higher voltages, additional precautions are necessary, particularly in regard to the drying out of the transformer and the oil. A slight amount of moisture in the oil used in a low tension transformer may not cause any trouble whatever, while the same amount in a very high tension transformer would prove disastrous. The best possible results are obtained by drying the transformer, and sometimes the oil, in a vacuum.

The boiling point of water is greatly reduced as the vacuum is increased, the boiling point under a 28-inch vacuum being approximately 40 degrees C. This lowering of the boiling point makes efficient drying possible at a lower temperature than when the drying is done at atmospheric pressure and consequently with less risk of overheating the insulation during the drying process. For this operation it is of course necessary to provide a vessel for containing the transformer preferably its own case, which can be made vacuum tight. The air is then exhausted and the trans-

former heated to a temperature sufficient to drive out the moisture. The oil can be heated in a separate tank in the same way and at the same time if proper arrangements are made. This drying out should be continued until the insulation resistance of the transformer shows it to be completely dry and the oil shows a very high dielectric test. The transformer case should then be filled with oil while the vacuum is maintained, the oil being introduced at the bottom at a moderate rate. This will result in the transformer case being completely filled, absolutely eliminating moisture and air bubbles.

Drying Oil.—Oil which contains water is not injured for use provided the water is removed. This may be done by allowing the water to settle at the bottom, drawing off all this water, and then drying out the moisture contained in the oil by heating it to a tempeature of 100 to 110 degrees Centigrade, until a test of the oil shows no moisture present.

Tests for Moisture.—A very satisfactory test may be made by placing a small amount of the oil in a cup and plunging into it a piece of iron which is heated to a temperature slightly below a dull red heat. Any hissing or crackling noises indicate the presence of moisture. The dielectric test affords a far more satisfactory indication. This test is made by means of a high potential transformer and a testing cup, which is shown in the accompanying illustration. This device consists of a 200-cubic centimeter graduated glass vessel, 1⅜ inches inside diameter, with a hole drilled through the bottom, through which the lower terminal is inserted. The testing terminals consist of two brass balls, ½ inch in diameter, fastened to $\frac{3}{16}$ inch rods. The upper rod passes through a clamp, which is connected to a micrometer screw actuated by a milled head. The lower terminal should fit in a socket so that it may be readily removed for cleaning. The bottom of the cup is made oil tight by the use of gaskets where the lower rod passes through the cup. An extension of the lower rod comes in



TESTING CUP

contact with a spring set in the base of the stand to which the line terminal is connected by means of a convenient binding post. Stops are provided so that the oil vessel may always be placed in the same position. The upper rod may slide up and down easily when the clamping screw is free, or may be engaged with the micrometer screw at any point for closely adjusting the gap. All parts are therefore readily accessible for cleaning, and the zero point of the gap may be quickly adjusted for each test by allowing the upper rod to slide down, so that the terminals are in contact, and then clamping to the micrometer screw. The apparatus is always filled to the 200 cubic centimeter mark (requiring a little less than 200 cubic centimeters of oil for each test). After trying numerous forms of testing apparatus for this purpose, this method has been adopted as the most convenient, and it has the advantage of requiring a comparatively small amount of oil for each test.

When a sample of oil is to be tested the spark gap in the cup is adjusted to a convenient size, usually 0.15 inches, and the voltage raised gradually till breakdown occurs. Dry oil should stand a test of at least 20,000 volts, and oil is frequently found which will stand 25,000 to 33,000 volts.

Scale and Dirt in Oil.—It occasionally happens that a small amount of scale and dirt is found in the oil, this coming from the inside of the cask during shipment. All oil which is shipped in metal drums should be strained through two or three thicknesses of cheese cloth before it is put into use. This will insure that the oil is free from any foreign matter which might be detrimental to the transformer.

Sampling.—In taking samples of oil for tests it is customary to use what is known as a "sneak" or "thief." This instrument consists of a tube approximately one inch in diameter with both ends reduced so as to have small apertures. This is introduced into the oil to be sampled, the upper end being kept stopped with the finger until the lower end of the sneak reaches the bottom of the oil. The finger is then removed, the oil from the bottom fills the tube, which is then drawn out by replacing the finger on the upper end of the tube, when the oil may be discharged into a sample bottle. This method of sampling insures that any water or dirt in the oil, which naturally settles to the bottom, will be taken with the sample.

MODERN PRACTICE IN SWITCHBOARD DESIGN

Part III

By H. W. PECK

SWITCHBOARDS FOR RAILWAY AND POWER SERVICE

THE diagram of connections of a typical 550-volt ground return railway installation is shown at Fig. 8. The equipment for each generator is the same as that described in connection with Fig. 5 except that a two-point voltmeter plug receptacle is used in connection with a differential voltmeter, and that the equalizer switches are mounted on pedestals near the generator. A two-point plug on the negative side is sufficient in this case because it is usual in starting to close the single-pole positive and equalizer switches and thus complete the circuit through the differential voltmeter. The equalizer switches are mounted upon pedestals so that they may be located near the machines, making the equalizing connections shorter and the connections on the back of the switchboard more simple. This improves the parallel operation of the machines and saves the expense of running all of the leads to the switchboard, which is a considerable item in a large station

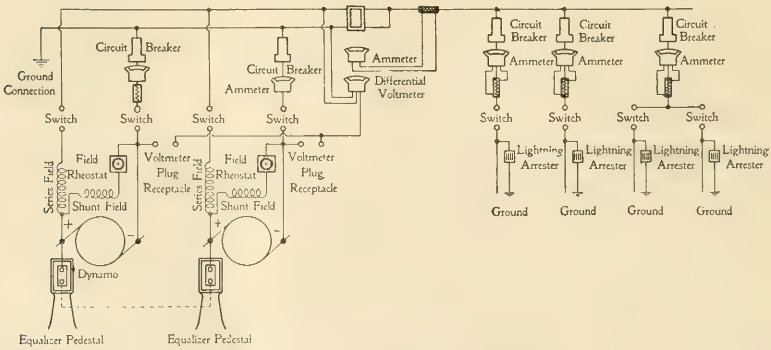


FIG. 8—DIAGRAM OF CONNECTIONS FOR DIRECT-CURRENT RAILWAY INSTALLATION

Some of the latest generators are designed for short shunt connection, consequently the shunt field connections differ in Fig. 8 from those in Fig. 5 (January Journal). In this type the positive side of the shunt field winding is connected between the

armature and the series field windings, so that the potential across the shunt field is unaffected by the drop through the series field coils and the regulation of the machine is improved. This connection could be effected by changing the field terminal at the switchboard from the positive lead to the equalizer lead, but as it is general practice to mount the equalizer switches on pedestals near the machines, the standard method of connecting the shunt winding is to connect its positive side to the equalizer terminal block and take the negative side to the switchboard. With the variable

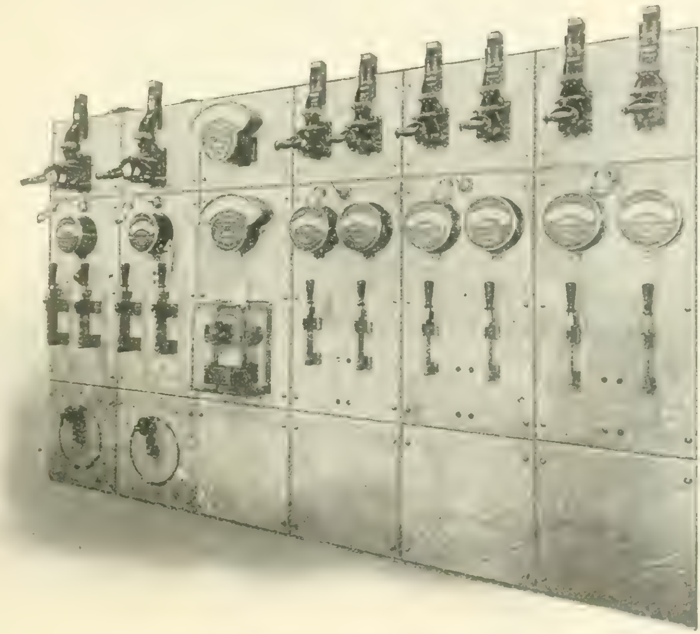


FIG. 9—SWITCHBOARD FOR RAILWAY SERVICE—FRONT VIEW

load of railway circuits it is advisable to equip the feeders with circuit-breakers and ammeters. It is usual also to connect a lightning arrester to each feeder so that in case lightning strikes the line the discharge will pass through the arrester to the ground without doing any damage to the apparatus in the station. Choke coils are often placed in the panel connections to further insure that the discharge will pass through the arrester. With equipments of this size it is usual to provide a load or station panel upon which is mounted a differential voltmeter, a totalizing

ammeter and a recording wattmeter. The diffential voltmeter comprises two coils so connected to the two circuits whose voltages are to be compared that they oppose each other in effect. The meter is double reading with the zero in the middle and indicates directly the voltage impressed on either coil alone. If there is pressure on both coils the meter will indicate the difference in pressure. It is usual to connect the meter as shown in Fig. 8, the positive bus-bar to the common point of the two coils, the negative bus-bar to another terminal and the plug receptacles to the third terminal. The voltage of an entering machine can then be directly compared with that of the bus-bars by inserting the plug in the receptacle of that machine. A four-point plug used in connection with a differential voltmeter is a source of danger, for if left in the receptacle of an idle machine it forms a direct connection between the positive bus-bar and the machine, which, when idle, should be dead to prevent danger to the attendant. The totalizing ammeter operates from a shunt connected in the positive bus-bar between the generator and feeder circuits thus indicating the total output of the station. The recording wattmeter is likewise connected in the positive bus-bar with its voltage coil across the bus-bars. The negative bus-bar is directly connected to the ground in as thorough a manner as possible.

EQUALIZER SWITCH PEDESTAL

Figs. 9 and 10 show respectively the front and rear views of a typical railway switchboard comprising two generators, one load panel and three double feeder panels. These panels are all two inches thick and two feet wide. The lower, middle and upper panels are respectively 21, 45 and 20 inches high. There are other standard widths besides two feet which are used when suitable, the narrowest panels conformable with good design being used. The frame is made of angle iron with a channel iron base. The division of the panel into three slabs is of advantage in case of breaking of the panel or repairs to apparatus.

In Fig. 9 the field rheostat face is shown mounted on the front of the sub-panel, where it can be easily operated with the

foot. It is more usual, however, to use the tetrapod mounting with the hand wheel just below the ammeter. The rear view, Fig. 10, shows the short negative bus across the generator panels

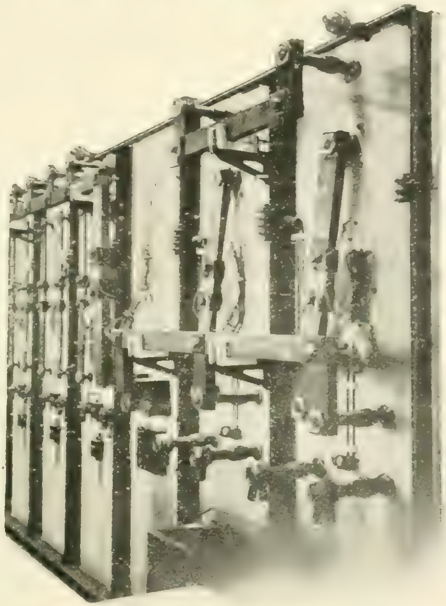


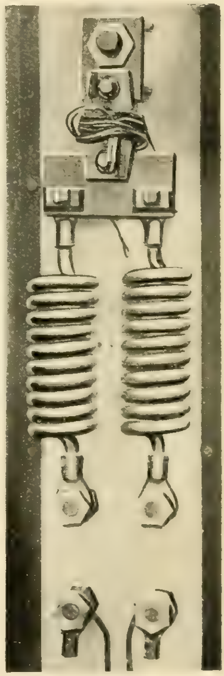
FIG. 10—SWITCHBOARD FOR RAILWAY SERVICE—REAR VIEW

with terminals for ground connection, the positive bus across the whole board, the connections on the panels, the mounting of the ammeter shunts, the machine and feeder terminals on the lower switch studs and the lightning arresters.

Railway systems sometimes do not use the ground for a return circuit. Lighting circuits are seldom grounded. In such cases the generator equipment is the same as that used in the grounded system, and the feeder circuits are provided with double-pole switches. Railway feeders often connect to separate sections of the trolley wires, and single-pole, double-throw switches are used in the circuit, the middle studs being connected to the lines, the upper and lower studs to the positive and negative bus-bars, respectively. With this arrangement the relative potential of the lines can be interchanged by reversing the switches. The advantage of this is that if two or more sections become grounded on one side, the

grounded side of each section can be made of the same polarity, so that no short circuit exists, and the fault can be repaired at any convenient time. This will not interfere with the operation of car motors since the direction of rotation of the series motor is the same without regard to the polarity of its terminals.

A double-throw system is often installed with this type of board, especially for light and power equipments. This requires double-throw switches on both generator and feeder panels, and two sets of bus-bars. The terminals for the machine and feeder leads are always on the circuit-breaker studs, while the two break jaws of the switches connect to the two busses. The principal advantage of this equipment over the single-throw system is the facility which it provides for taking loads of different voltage, or regulation characteristics. With a light load the feeders may all be taken from the same bus. With a heavy load, either the longer circuit can be fed from one bus at potential above normal, or the light and power circuits can be separated if the regulation is not satisfactory.



CHOKE COILS ON BACK OF SWITCHBOARD

A second bus is often run parallel with the feeder panels or part of them, and fed from the main bus through a series-wound booster. This increases the bus voltage with an increasing load just as series field coils boost the voltage of a compound-wound generator. This arrangement requires an extra panel for the control of the booster motor. The current for both machines is taken through the same circuit-breaker, which is arranged to trip from a series coil in the motor circuit or a shunt coil whose circuit is closed by the opening of the automatic starting switch of the motor. This is done to prevent the possibility of having the motor circuit open and the booster motor in circuit, in which case it would run as a series motor at a dangerous speed.

ELECTRIC RAILWAY BRAKING

PART V

By E. H. DEWSON

THE TRANSMISSION GEAR OF AN AIR BRAKE EQUIPMENT

THIS important part of a car equipment includes the brake cylinder in which the energy of the compressed air is expended, the brake shoes which transform the kinetic energy of the moving car into heat, and the foundation brake rigging by means of which the force exerted upon the piston is transmitted to the brake shoes.

In designing such a gear the first question to be decided is the total amount of brake power that may be effectively applied to the wheels. The adhesion of the wheels to the rails is the limiting factor of the brake power, and it is a maximum when there is no slipping between the wheels and the rails, i. e. when the particles of each which are momentarily in contact, are relatively at rest. As this condition exists for all speeds it is evident that the adhesion of the wheels to the rails is independent of the speed. In the Galton-Westinghouse tests the adhesion was found to range from .19 to .35 of the weight on the wheels and averaged about .25 for clean dry rails. Upon wet or greasy rails it averaged .18, but with sand on such rails it never fell below .20 and rose in some cases as high as .40, which demonstrates the necessity of a good supply of sand and efficient means for its application on roads where the rails are liable to become greasy. Dynamic friction, however, decreases as the speed increases; the coefficient of friction of a steel-tired wheel sliding, or technically "skidding" upon a steel rail, ranges from .242 when just coming to rest and .088 at 6.8 miles per hour to .027 at 60 miles per hour, which explains why the poorest kind of a stop is made with the wheels skidding. The coefficient of friction of brake shoes upon wheels ranges from .27 at 5 miles per hour to about .10 at 60 miles per hour. So to produce the same retarding effect at 60 miles per hour, about three times the pressure should be applied to the shoes at the high speed as could be safely applied at the lower speed.

The following table gives approximately the proportion which the pressure applied to the wheel shoes should bear to the total weight upon the braked wheels, to produce a brake friction just equivalent to the adhesion of the wheels to the rails.

Speed		Approximate Ratio of Total Pressure on Brake Shoes to Total Weight on Braked Wheels.			
		Coefficient of Adhesion			
Feet per Second.	Miles per Hour.	0.30	0.25	0.20	0.15
11	7½	1.20	1.04	0.83	0.60
22	15	1.41	1.18	0.94	0.70
29	20	1.64	1.37	1.09	0.82
44	30	1.83	1.53	1.22	0.92
59	40	2.07	1.73	1.38	1.04
73	50	2.48	2.07	1.65	1.24
88	60	4.14	3.47	2.77	2.08

From this it will be seen that with the average coefficient of adhesion of .25 a braking power of 90 percent. of the weight of the car may be applied without danger of skidding the wheels at low speed when the coefficient of friction of the brake shoes is a maximum. It is also evident that under the same condition of rail, but at 60 miles per hour, 300 percent. brake power could be safely applied, provided this power were reduced as the speed decreased. An ideal brake would be one by which the maximum safe pressure for the existing speed is automatically applied and then decreased as the speed diminishes. In the hands of a skillful operator the straight air brake can be manipulated to approximate this result, and on some interurban roads where the condition of the rails is excellent a brake power as high as 150 percent. of the weight of the empty car has been successfully used, but so high a ratio would be dangerous under ordinary conditions, or with the majority of motormen. A safe practice is to apply a 90 percent. brake power to idle axles and 100 percent. to those equipped with motors, because of the rotative energy stored up in their armatures, which is equivalent to 3 to 6 percent. of the inertia of the mass of the car. On some roads it is necessary to use a hard steel tire and a hard brake shoe having a low coefficient of friction, consequently a still higher brake power must be employed to obtain the same retarding effect.

While primarily the subject of leverage is one of statics, or forces in equilibrium, the necessity of providing wheel shoe slack,

together with the unavoidable springing of various members and wear at joints, introduces the factor of space. Thus the determination of the size of brake cylinder required for a car of given light weight is a question of area of piston, pressure per square inch and stroke. Standard practice in steam railroad service has fixed the maximum emergency pressure at sixty pounds per square inch with a normal piston travel of eight inches. Consequently with the application of air brakes to electrically propelled cars the same maximum cylinder pressure is retained, as by so doing the proper braking power would still obtain, should the system ever be changed from straight to automatic air, or vice versa. Incidentally a good standard is maintained. The piston travel is equal to the average amount of the wheel shoe slack or clearance multiplied by the total gain by leverage, if we leave out of consideration that due to springing of levers, etc. Although leverage ratios as high as 16 to 1 have been used with air brakes, the best practice ranges from a maximum of 12 to 1 for eight-inch cylinders to 10 to 1 for fourteen-inch. The following table of sizes of cylinders and leverage ratios, with corresponding weights of empty cars, is based upon the above considerations:

Diam. of Cylinder in Inches.	Force of Piston at 60 lbs.	Total Leverage Ratio.	Weight of Car with brake power equal to 90	100	110
8	3,000	12 to 1	40,000	36,000	32,750
10	4,700	11 to 1	57,800	51,700	47,300
12	6,700	10¾ to 1	80,000	72,000	65,500
14	9,200	10 to 1	102,300	92,000	83,600

Owing to the fact that the bodies of electrically propelled cars are often built by one manufacturer and the trucks by another it is convenient to consider the foundation rigging as divided into two parts, i. e., that which is mounted upon and ordinarily supplied with the trucks, and that which is suspended from the car body. The hand brake gear is sometimes entirely separate from that of the air brake, but more generally the entire truck brake equipment and a portion, if not all, of the body rigging, is utilized. It therefore will be mentioned in this article only in so far as it has a bearing on the air brake equipment.

Having determined the proper size of brake cylinder for the weight of car under consideration, we will take up the brake equipment of the truck. Its essential points are as follows: a distribution

of the brake pressure between the wheels in proportion to the weight upon each, the greatest rigidity practicable, simplicity in design, durability and maximum efficiency. To obtain the latter the friction and cramping of the different parts upon each other must be avoided and the force necessary to draw the shoes away from the wheels, when the brakes are released, must be reduced to minimum. Whenever practicable the brake shoes should be hung between the wheels, and the hangers so inclined that the shoes will swing clear from the wheels by gravity. With shoes hung outside an application of the brake causes the forward end of the truck frame to tilt down, thereby tending to slack off the pair of shoes at this end. The other end of the truck tilts up, which tightens these shoes and skids this pair of wheels, because the friction at the different connections prevents the pressures from equalizing under the altered conditions. The advantages of hanging the shoes inside are very exhaustively considered in Mr. R. A. Parke's paper on "Railroad Braking," read

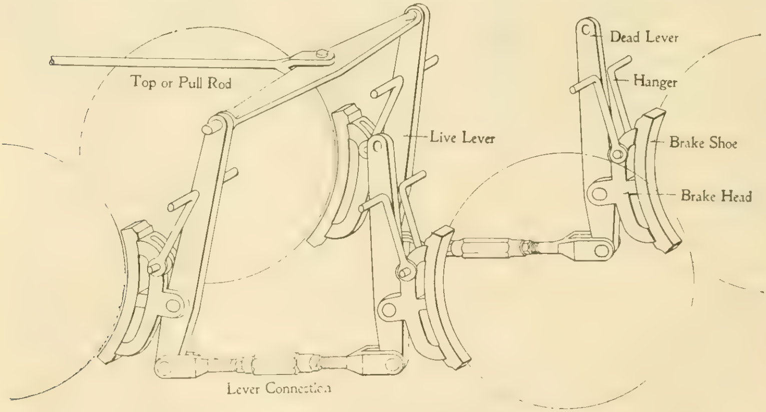


FIG. 15—TRUCK BRAKE RIGGING FOR ELECTRIC CAR

before the A. I. E. E., December 19, 1902. The release springs as ordinarily supplied and operated without adjustment to compensate for the wear of the shoes, take an extraordinary amount of power before the shoes even come in contact with the wheels, and for this reason a gravity release is preferable.

The radius bar is an unsatisfactory device for compensating for the excessive swivelling required of trucks in electric service. It is preferable to make a connection direct to the live lever close to the center pin, or to a bar connecting the upper ends of the two live levers when there is one on each side of the truck as shown in Fig. 15.

AN APPRENTICE TO AN APPRENTICE

———, Jan. 12, 1905.

Dear N———:

No! I haven't forgotten you at all. Just been working all the time, Saturday, Sunday and Monday nights, Tuesday, Wednesday and Thursday during the day. We work most of the time, at least seven days in the week. My work consists of inspecting apparatus on the cars on a certain part of the line of the railway, and fixing up any trouble, not directing it, nor showing someone else how it should be done, but actually putting on overalls, climbing down into a pit under the cars and working like h——. My hands are in such horrible shape that I wouldn't think of dining in a respectable cafe. W—— and I are working together, he being my boss, in a car barn where, till to-day, everything except a part of the heating apparatus and some of the workmen were frozen. To-day it thawed a little, i. e. inside the car barn. That's what we are up against. I'm not discouraged at all and I like my job and the prospects for advancement. By all means get into either alternating-current single-phase or multiple control railway work. When you learn anything learn it for keeps, and when you work in the shop actually do the work. That is the mistake that most men make. They think (I was as guilty as the rest) that the object of the game is to learn how to do things by watching someone else do it. Get that out of your head as soon as possible. Don't just try to learn how to show someone else how to do the thing. Learn to do it yourself by actually doing it. Chipping and filing are not very attractive things in themselves, but during the one week that I have been here, I have kicked myself a hundred times because I didn't learn both when I had the opportunity. I made a fool out of myself not working all the time that I was in the shop and, if possible, I want to warn my friends from making the same mistake. You said that you wanted railway work and construction. I think your choice is very good. If you profit by my mistake and do as I suggest, work every minute and you will be the goods when you leave the apprenticeship course.

Also I want to advise you to go to see people—not play the society game and wear yourself out, but meet and learn to know all kinds of people. It will help a lot. Don't think that people in your own station in life are the only ones worth knowing. It is worth while to know all sorts and conditions of men and not only to know them, but to be liked by them. Up to the present it has been almost against my principle to make use of hot air. From now on I intend to use it to a certain extent. Don't think it beneath you to jolly a foreman into getting anything you want out of him. If you get what you want, that fact means that you are making good just as much as doing anything else worth while and will count. Go to The Electric Club. A man can learn a lot there. It isn't very easy, but make yourself do it. The officials of the company are right in saying that there are opportunities in electricity. It looks tough to one to see good men trampled on in a certain way, but the company has enough apprentices to make it possible for the men who are both good men and energetic men to be given the preference.

Be the man they want. First, work with your own hands if you are in the shop, but let your brain work at the same time. Second, get all the information and good out of the course that you can by getting the foremen, everyone with whom you come in contact, to do what you want. Third, go to The Electric Club as much as possible. Fourth, meet and know people in Pittsburg. Show this to C——— and especially to S——— who is still in the early stage of the course.

Hoping to hear from you some time soon, I am as ever,

Sincerely,

J———.

P. S.—This may seem a very unnecessary lot of advice, but I realize my own mistake and don't see any good reason why you should make the same one without an attempt on my part to stop you. I'll send that eight dollars when my back pay arrives from Pittsburg.

FACTORY TESTING OF ELECTRICAL MACHINERY—XIII

By R. E. WORKMAN

EFFICIENCY

The efficiency of alternators is always taken with the current in phase with the terminal e.m.f. It is found as in the case of direct-current generators, by adding the total losses in the machine at a given load to the total output, both being expressed in kilowatts, thus obtaining the mechanical input. The efficiency is the ratio of the total output to the total input. The following example will indicate the method of calculation:

Consider the same machine whose iron loss, saturation and regulation curves are given in Figs. 54 and 65.

Armature resistance per phase at 50 degrees centigrade .00405 ohm.

Field resistance at 50 degrees centigrade=.850 ohm.

Efficiency at 2000 amperes, total.

$I\ R$ volts=4.05.

Copper loss in the armature$=\frac{1}{2}I^2R=\frac{1}{2}$ $(2000^2\times.00405)=$ 8100 watts.

Copper loss in the field$=I^2R=(93.8)^2\times.850=7480$ watts.

Iron loss=27600 watts from iron loss curve at 504 volts.

Total loss=43180 watts.

Output=1000 kilowatts.

Input=1043 kilowatts.

Efficiency=95.7 percent.

Other points on the curve are found in the same manner, and values of input, output and efficiency plotted to amperes load as shown in Fig. 65.

Temperature Tests

As in the case of direct-current machinery, temperature tests of alternators are taken in exactly the same way as regulation tests, by running the machine under full-load. This, however, applies only to the smaller machines, as it requires a large amount of power to test a large machine under full-load conditions. Large machines

are generally tested on open-circuit with a field current equal to the field current at full load and normal rated voltage. The only loss which is not represented in this test is that in the armature copper, and, as this is one whose effect can be easily foretold from experience, the armature resistance being known, the test is a fairly complete one.

Where the temperature test is made by means of resistance load, it is carried out in almost exactly the same manner as in the case of direct-current machines. The connection of the polyphase alternators to the resistance is made as described under regulation, November JOURNAL, p. 620.

The connections for a temperature test on resistance load of a three-phase alternator, are shown in Fig. 59, December JOURNAL, p. 673.

If the temperature test on resistance load is not possible, the test made is one on open-circuit with the above mentioned field current. This test is made under exactly the same connections as the iron-loss test, the voltage of the machine being measured as well as its field current.

It is obvious that this test is not complete, the effect of the armature copper loss in raising the temperature being left out. As mentioned above, however, it is possible from experience and the results of previous tests, to obtain a very fair estimate of the temperature rise under full-load conditions from that under the conditions of this test.

The temperatures taken, whatever the method of testing, are those of;

Armature copper,
Armature iron,
Separate field copper,
Compensating field copper (when present),
Collector rings,
Surrounding air.

The same precautions as those mentioned in connection with direct-current machines must also be observed here.

COMMERCIAL TESTS

The tests usually made are:

Polarity,
Iron loss, friction and windage, check on the armature windings and saturation,
Temperature,
Insulation.

Polarity—This test is much more important in the case of alternating-current generators than in the case of direct-current generators because: (1) Owing to the large number of poles in large, slow-speed alternators, there is a much greater chance of a mistake being made in assembling the machine. (2) The effect

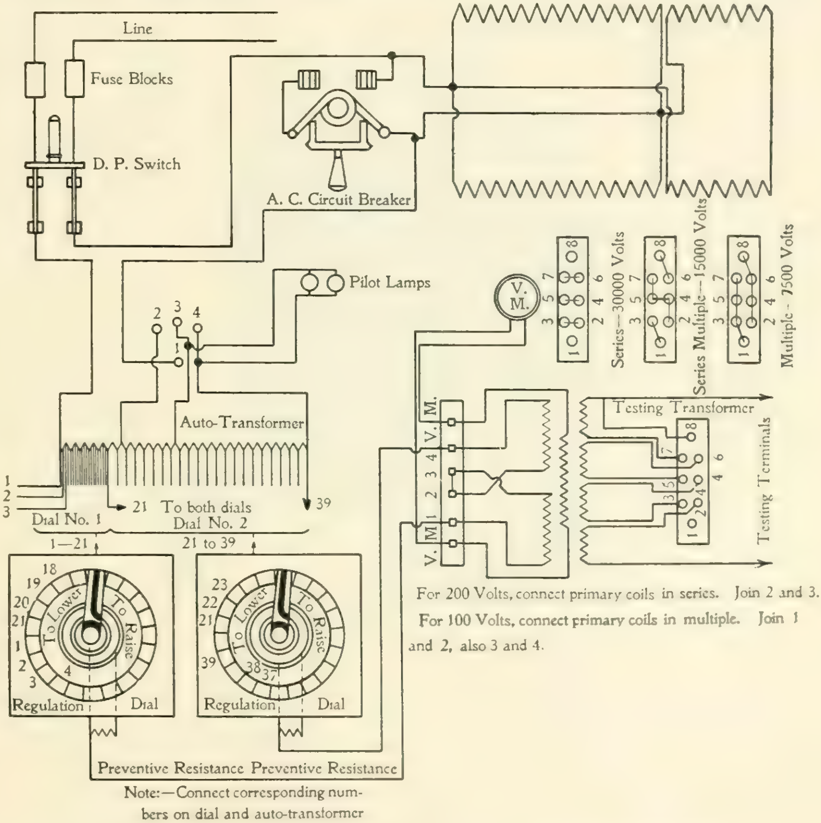


FIG. 66—DIAGRAM OF CONNECTIONS FOR A 30,000-VOLT TESTING SET

of a reversed coil is not nearly so evident as in the case of a direct-current machine.

The test may be made using exactly the same methods as those described for direct-current machines.

Iron Loss, Friction and Windage, and Saturation—These tests are not made as commercial tests except in the case of large machines. Where they are made, the tests are exactly the same as those described under experimental testing.

CHECK ON THE ARMATURE WINDING—This is simply a reading of the open-circuit e.m.f's of the machine, running as a generator, and may be taken as a part either of the saturation or of the regulation test. The reading is taken simply to see that the taps from the armature windings have been brought out at the right places, a mistake being indicated by a want of balance in the voltage of the several phases.

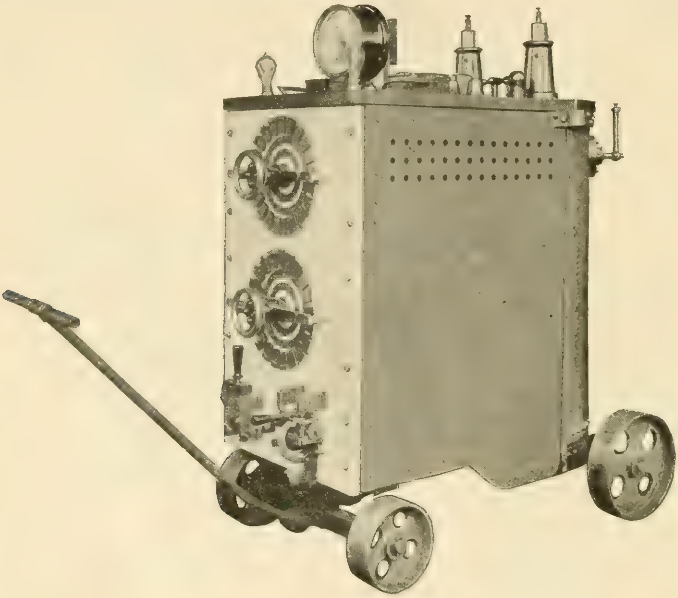


FIG. 67—A 30,000 VOLT TESTING SET

TEMPERATURE—The temperature test usually made is that on open circuit with field current necessary to obtain full voltage at full-load. This is generally taken at $\frac{7}{6}$ of the full-voltage field current on no-load.

INSULATION—In the case of low-voltage alternators, the insulation test is exactly the same as that made on direct-current machines. Where tests at voltages of 15,000 or above are made, special precautions must be taken:

(1) That the capacity of the testing transformer is great enough to supply charging current to the apparatus tested, considered as a condenser, without appreciable rise in the terminal voltage.

(2) That the wave form is not far different from the sine.

(3) That choke coils of very considerable reactance are placed

in series with the spark gap, if one is used to determine the voltage. If choke coils are not used very large oscillatory disturbances may result when a spark passes at such a high frequency as to make the impedance in one turn of the testing transformer and of the machine tested so great in comparison with the resistance of the insulation, that the oscillatory charging current of the machine regarded as a condenser will pass through the insulation as a path of comparatively low impedance, instead of passing around the turns which have a very great impedance for currents at high frequency.

(4) That the voltage applied is brought up gradually to a maximum and not by large steps. Fig. 66 shows the connections of special testing set used for voltages of 15,000 volts and over. Fig. 67 is a photograph of a testing set for a maximum of 30,000 volts.

SYNCHRONOUS MOTORS

The polyphase synchronous motor is essentially a reversed polyphase alternator, just as the direct-current motor is a reversed direct-current generator.

While a comprehensive explanation of the operation of the synchronous motor would be out of place in this series of articles it is, nevertheless, worth while to mention two operating characteristics of these motors before describing the tests made on them.

(1) The synchronous motor will operate at only one definite speed. Consider an armature conductor under one of the poles of the field, the machine being assumed to have a rotating armature. If at any instant a current flows in the conductor, there will be a mechanical force applied to the conductor, tending to move it in a definite direction at right angles to the direction of the lines of force of the field. If the armature, while the direction of the current flowing in it remains unchanged, be now turned so as to bring this conductor into a similar position under the next pole, the mechanical force impressed on the conductor will be in the opposite direction. Hence if the armature is to rotate continuously, the current in each conductor must reverse in direction in the same interval that the conductor moves from one pole to the next, i. e., the current must alternate and the speed of the motor for a given frequency of the supply circuit must be equal to the number of alternations per minute divided by the number of poles of the motor.

(2) The element in the operation of the synchronous motor by means of which the necessary balance between the mechanical

load on the motor on the one hand and the electrical energy taken by the motor on the other hand is maintained, is the phase relation between the impressed e.m.f. from the supply circuit and the counter e.m.f. generated in the motor.

In every electric motor when the load on the motor is increased the energy taken by the motor is automatically increased to take care of the increased load. While the increase in energy is primarily due to the increase in load, it is directly due to some electrical change in the motor circuit. In a direct-current shunt motor when the load is increased the motor slows down. This decreases the counter e.m.f. of the motor and is the direct cause of the increase in current taken by the motor. In an induction motor an increase in load likewise causes a decrease in speed, which increases the voltage generated in the motor secondary, and thus increases the secondary current. This, by magnetic induction, increases the current taken by the motor primary. In the synchronous motor an increase in load also causes a decrease in speed, but this decrease is only momentary. The speed decreases for an instant, so that the motor armature falls back slightly from its position relative to the impressed e.m.f. After this momentary decrease in speed the motor continues to revolve at synchronous speed, but with the armature in this new relative position. This change in position results in a change in the relative phase position of counter e.m.f. and impressed e.m.f. such that the counter e.m.f. offers less opposition to the impressed e.m.f., so that the larger current flows in the motor.

The experimental and commercial tests made on synchronous motors are practically the same as those made on synchronous generators. The machines depend upon exactly the same principles. There need be no speed tests as in the case of direct-current motors, since the speed bears a constant ratio to that of the generator which supplies the power. The analogue of the regulation curve for synchronous generators, is the curve expressing the relation of field amperes to armature amperes at unit power-factor.

The efficiency test of a synchronous motor is taken at unit power-factor, and as a rule is calculated from losses in exactly the same way as for a direct-current machine.

TEST TO FIND RELATION OF FIELD AMPERES TO ARMATURE AMPERES AT UNIT POWER-FACTOR.

This test gives a basis for the calculation of the efficiency curve of the motor at unit power-factor. It has, however, no meaning

unless the e.m.f. wave forms of the motor and of the generator are the same.

Preparations for Test.—The motor is belted to a direct-current generator of sufficient size to transmit the full load of the motor when loaded on resistance. The connections are made to the source of polyphase power through the testing table shown in Fig. 56 (See November JOURNAL), except that in order to start the motor the direct-current generator to be used for loading must be connected to some source of direct-current power as a motor.

Conduct of Test.—The direct-current machine is started as a motor in the usual way and the synchronous motor is brought nearly to synchronous speed when it is finally synchronized as described in the JOURNAL for December. The direct-current machine is then disconnected from the power circuit and connected as a direct-current generator to a resistance load, an ammeter being placed in the generator circuit. In taking readings the separate field of the synchronous motor is varied for the various loads. The power-factor is held to its unit value throughout the test. The frequency and voltage of supply are held constant, and readings are taken of the current in the motor armature circuits.

The power-factor is held at unity by adjusting the motor field current, with a given load on the generator, until the motor armature current is a minimum. Where the apparent watts are a minimum, it is obvious that they must be equal to the true watts, i. e., the power-factor must be unity.

In a similar way a series of these readings is taken from which a curve is plotted with armature amperes as absicssae and field amperes as ordinates.

TEMPERATURE TESTS.

In the temperature test, running as a motor, the machine is belted to a direct-current generator loaded on resistance. The same connections are used as in the test described above. The machines are started up in the same way and the load is applied by means of resistances in the generator circuit. The test may also be made by running the machine as a generator with resistance load and the full-load current in its circuits.

It is very often quite sufficient to run the machine as a generator on open-circuit with $\frac{7}{6}$ full field current.

COMMERCIAL TESTS.

The commercial tests made are exactly the same as those for alternators.

APPLICATIONS OF ALTERNATING-CURRENT DIAGRAMS

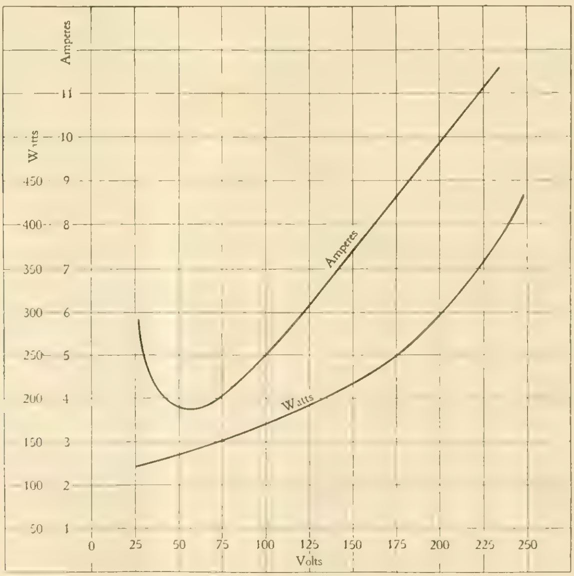
IX—HEYLAND DIAGRAM, Concluded

By V. KARAPETOFF

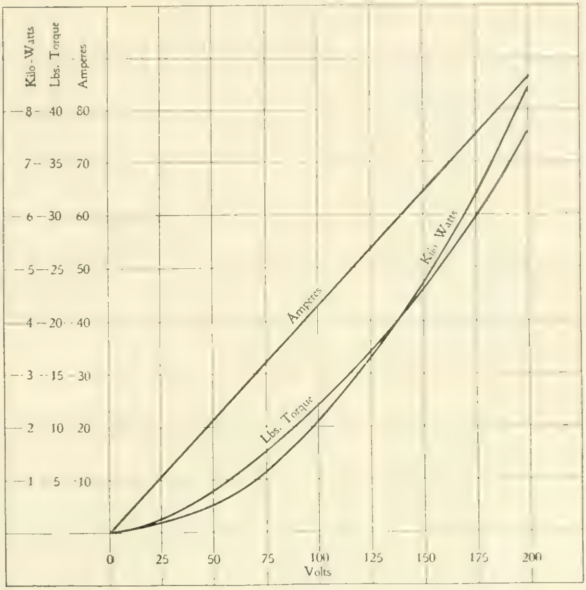
The following guide for using the Heyland diagram has been arranged by the author in co-operation with Mr. E. R. Cross. The specific application selected is that of a two-phase, 60-cycle, 200-volt, five-horsepower induction motor, the characteristic curves of which are here also given.

The outline, which is arranged in a table under three heads, construction, explanation and illustration, presents in a concise and convenient form this method of analyzing the performance of an induction motor. As stated in a previous chapter, the Heyland diagram is not applicable to motors of less than three horsepower.

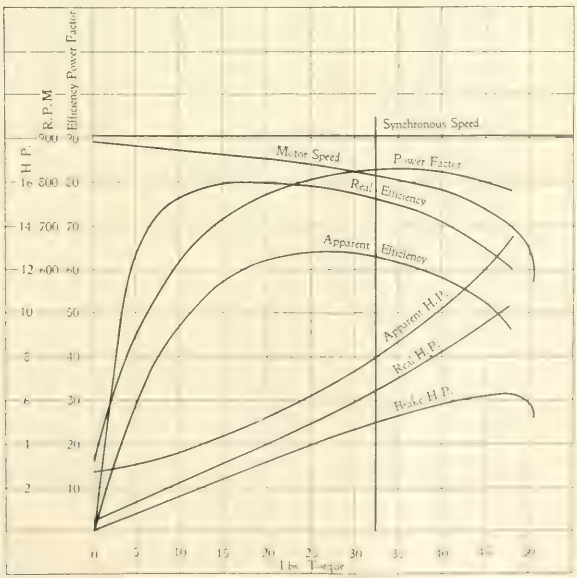
In closing this series of lectures it is only proper to note that there are other problems that may be solved by vector diagrams, such as those relating to synchronous motors, the parallel operation of alternators, etc. These are, however, only modifications of the cases before discussed. With a thorough understanding of the applications of vector diagrams to transmission lines, transformers, alternators and induction motors (which have been set forth in previous articles) the other problems will present no new or difficult complications.



RUNNING SATURATION CURVE OF A 200 VOLT, 60 CYCLE, EIGHT POLE, FIVE HP, TWO-PHASE INDUCTION MOTOR



LOCKED SATURATION CURVE OF A 220 VOLT, 60 CYCLE, EIGHT POLE, FIVE HP, TWO-PHASE INDUCTION MOTOR



POWER CURVE OF A 200 VOLT, 60 CYCLE, EIGHT-POLE, FIVE HP, TWO-PHASE INDUCTION MOTOR. CALCULATIONS BY HEYLAND DIAGRAM

THE HEYLAND DIAGRAM FOR POLYPHASE INDUCTION MOTORS

E=Constant impressed voltage.

i_L =Primary amperes, armature locked.

r_1 =Primary ohmic resistance.

N=Synchronous speed in R. P. M

	CONSTRUCTION	EXPLANATION	ILLUSTRATION
POWER FACTOR	(1) At the extremity A of the base line AB erect a perpendicular, which can be divided conveniently into 100 parts, as AF, and with A as a center describe the quadrant FD. The ordinate of any point on this arc, as F_4, will measure the power-factor.	(1) In the quadrant diagram, AF is the direction of impressed e. m. f. Therefore, any current vector, as AC_4, will intersect the arc FD at a point, the ordinate of which is equal to $Cos\angle FAF_4$, or to the power-factor for that current.	(1) The Heyland diagram applied to a 5 hp. 200 v., 8 pole, 7200 Alt., 2-phase Induction Motor. From readings taken on test: N=Av. synchronous speed=902 r. p m. Average resistance at 25 degrees C.= 0.98 ohms per phase. E=Constant impressed e. m. f.= 200 v.
CIRCLE OF INPUT	(2) From A lay off the lines AC_0, AC_L, having a length equal to the currents at no-load and locked positions respectively (at normal voltage), and at an angle equal to the power-factor (ordinates of F_0 and F_L) under these two conditions; and then through the points C_0, C_L draw the semi-circle $CC_4\,C_L B$, having its center O_0 upon the line AB.	(2) As shown by the theory of induction motors and confirmed by experimental test, the extremities of all vectors of primary current drawn from A lie on the arc of a semi-circle $CC_1C_L B$, between the limits AC_0 (current at no-load) and AC_L (current, armature locked). This is the circle of *input*, as input at constant voltage is proportional to amperes.	(2) From saturation curves, at full voltage: Running. 9.82 Amps., 294 Watts, 15.0 per cent. Power-Factor. Locked. 86.2 Amps., 836 Watts, 48.5 per cent. Power-Factor.
CIRCLE OF TORQUE	(3) Connect C_L to B, and mark on this line the point T_L, such that $C_L T_L = AB \times \frac{i_L r_1}{E}$, where i_L is the locked current at normal voltage (represented on the diagram by AC_L) and r_1 is the equivalent primary resistance ($=\frac{1}{2}\times$ resistance per phase). Through this point draw the arc $CT_4T_L B$ having its center at O_T.	(3) The point T_L divides the line $C_L B$ into parts proportional to the ohmic drop in primary and secondary respectively. The length AB is taken as a scale of primary voltage and the segment $C_L T_L$ (drop in primary winding, armature locked) laid off to the same scale; primary ohmic drop at other loads is represented by similar segments, as C_2T_2, C_3T_3, C_6T_6, on lines 2, 3, 6. The arc $CT_4T_L B$ passing through this point (T_L) lies on the circle of *torque*, or power delivered to secondary.	(3) $i_L = 86.2$ Amps. $r_1 = \frac{0.98 \times 1.1}{2} = 0.54$ ohms (at 50 degrees C.) E=200 Volts. $i_L r_1 = 86.2 \times 0.54 = 46.6$ Volts=primary ohmic drop, armature locked. $C_L T_L = AB \times \frac{46.6}{200} = 0.233 \times AB$.

CIRCLE OF OUTPUT	(4) Draw a perpendicular to the line $C_L B$ at B, intersecting the vertical through $O_C O_T$ at the point O_P; and with O_P as a center construct the arc CP_1B.	(4) The arc of the third circle, as thus drawn, is tangent to the line $C_L B$ at the point B, reducing this segment by the length $T_L B$ proportional to the secondary ohmic drop. This is therefore the circle of *output*, or power available for mechanical work.	
SLIP	(5) From C_L draw the line $C_L S$, making an angle with $C_L B$ equal to $\angle BCT_L$, as shown by dotted arcs. The ordinate of any point S_1 on the line $C_L S$ (or of the corresponding point S_1^1 on any line parallel with it, as $S^1S_1^1$) will measure the slip to a definite scale.	(5) Slip, as the ratio of the secondary current to the secondary flux, should be measured (at any load P_1) by the ratio of CT_1 to T_1B. But BSS_1 and $BS^1S_1^1$ are similar to the BT_1C, so that this ratio $\frac{CT_1}{T_1B} = \frac{SS_1}{BS} \left(\text{or} = \frac{S^1S_1^1}{BS^1} \right)$ Therefore, as the bases BS and BS^1 are constant, the slip is proportional to SS_1 (or $S^1S_1^1$), or to the ordinates of these points. Upon the line $S^1S_1^1$, small values of slip can be read to an enlarged scale.	
SCALES	(6) Let a length equal to 10 of the smallest divisions on the co-ordinate sheet be designated by a, and let $1a = n$ amps., be chosen for the scale of current. Then: $1a = (nE)$ Watts $= \left(\frac{nE}{746}\right)$ hp. $1a = \left(7.04 \times \frac{nE}{N}\right)$ lbs. torque. $1a = \left(\frac{N}{\text{ordinate of } C_L}\right)$ r. p. m., referred to line SC_L. $1a = \left(\frac{N}{\text{ordinate of } C_L} \times \frac{BS}{BS^1}\right)$ r. p. m., referred to line $S^1S_1^1$.	(6) Any number of amperes (n) put into a motor at a voltage E is equivalent to an input of (nE) Watts, or $\left(\frac{nE}{746}\right)$ hp. As torque is the ratio of energy to speed, this is equal to $\left(\frac{nE}{746} \times \frac{5250}{N}\right) = \left(7.04 \frac{nE}{N}\right)$ lbs. at 1 ft. radius. The total length $C_L S$ corresponds to a slip of N revs. per min. (or 100%), as C_L is the locked point. Therefore, the normal scale of slip $= \left(\frac{N}{\text{ordinate of } C_L}\right)$ r. p. m.	(6) $1a = n = 5$ amps., arbitrary. $1a = 5 \times 200 = 1000$ Watts. $= \frac{5 \times 200}{746} = 1.34$ hp. $1a = \frac{902}{8.25} = 109.3$ r. p. m. (normal scale, line SC_L). $1a = 109.3 \times \frac{271}{13.35} = 22.2$ r. p. m. (enlarged scale, line $S^1S_1^1$).

E=Constant impressed voltage.

i_L=Primary amperes, armature locked.

THE HEYLAND DIAGRAM FOR POLYPHASE INDUCTION MOTORS

r_1=Primary ohmic resistance.

N=Synchronous speed in R. P. M.

READING OF VALUES FROM DIAGRAM

CONSTRUCTION

(7) From B draw any line, as 4, cutting the three circles at C_4, T_4, P_4, and the slip line at S_4^1. The ordinates of these points will give complete information about the performance of the machine at this particular load. For any other line (as 2, 3, 6,) corresponding values may be obtained, furnishing data for the plotting of curves. Thus, using the scales given above, we get: length $AC_4 \times n$=primary amperes.

length $AC_4 \times \frac{nE}{746}$=apparent hp. input.

Ordinate of $C_4 \times \frac{nE}{746}$ = real hp. input.

(Ordinate of P_4 — ordinate of C_0) $\times \frac{nE}{746}$=brake hp. output.

(Ordinate of T_4 — ordinate of C_0) $\times 7.04 \frac{nE}{N}$ = lbs torque.

Ordinate of S_4^1 x scale of slip=slip (in r. p. m)

To get the power-factor draw the line AC_4, intersecting the power-factor quadrant in F_4. Then ordinate of F_4= power-factor (AF=100%).

EXPLANATION

(7) With the line AB taken as a scale of primary voltage, AC_4 will represent the leakage component and BC_4 the total working component. This latter is reduced successively by C_4T_4 (primary ohmic drop) and T_4P_4 (secondary ohmic drop), the ordinates of these points thus representing the relative inputs.

Primary amperes, to scale already decided upon (see section 6).

(Primary amperes x impressed voltage) ÷ 746=apparent hp. input.

Working component of apparent hp. input=real hp. input.

Theoretical output — no-load losses= brake hp. output.

Theoretical torque — internal torque= lbs. torque available.

Slant distance SS_1 ($C_L S$=100 per cent. slip : : ordinate of S_4 : : ordinate of S_4^1 = slip in r. p. m. $\left(\text{to scale } \frac{BS}{BS^1}\right)$.

Special points:

Max. power-factor=ordinate of F_4 (on tangent line AE_1)

Max. input=ordinate on O_c to circle of input.

Max. output = ordinate on O_c to circle of output — ordinate of C_0.

ILLUSTRATION

(7) For line BC_4, the full-load values are as follows:

Prim. amps.=5 x 5.99=29.95.

App. hp.=1.34 x 5.99=8.025.

Real hp.=1.34 x 4.91=6.58.

Brake hp.=1.34 x (4.03—0.3) = 5.00.

Lbs. torque=7.8 x (4.47—0.3)=32.55.

Slip (in r. p m.)=22.2 x 4.1=91.

Power-factor=82.2 per cent.;

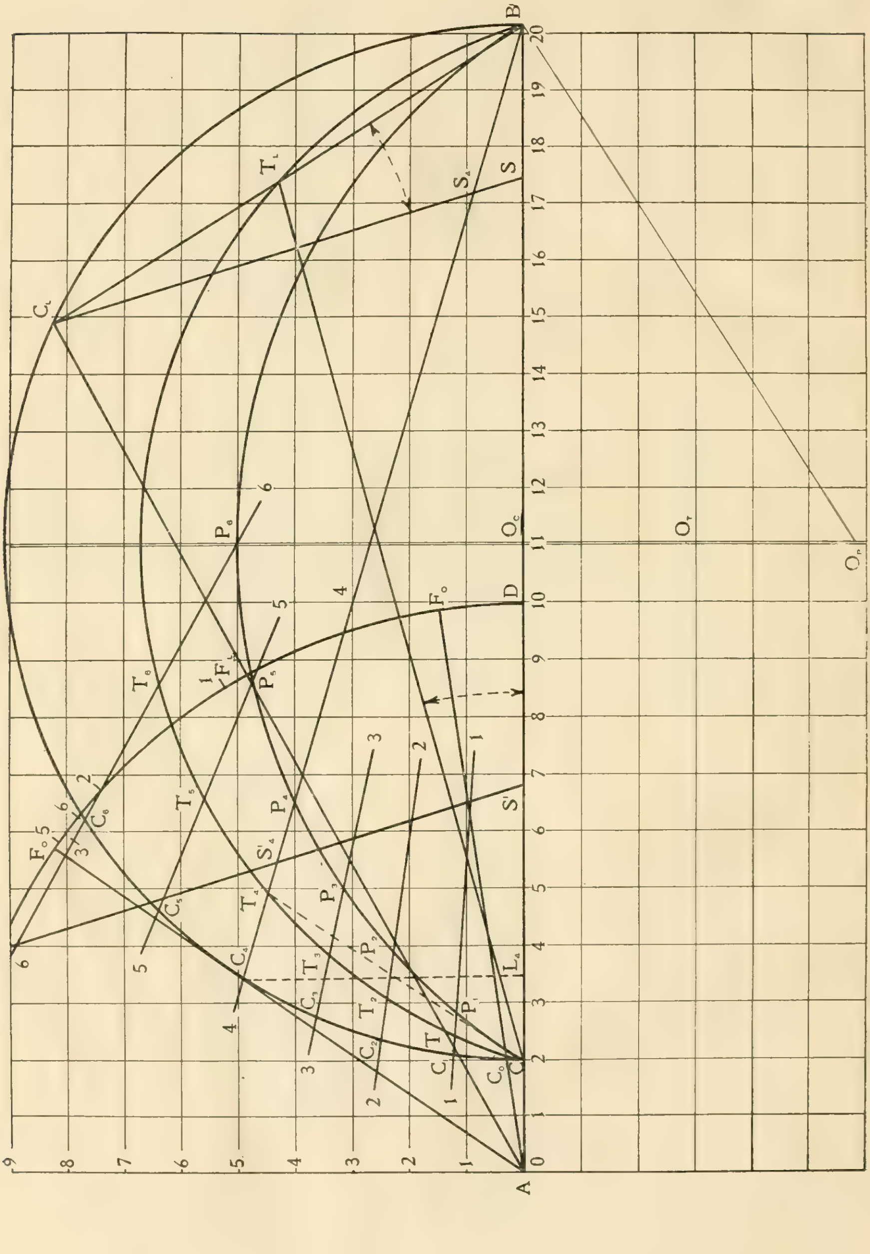
Real eff.=76.0 per cent.;

App. eff.=62.3 per cent.

TABULATED VALUES FOR DIFFERENT LOADS.

	1	2	3	4	5	6
Prim. amps.	11.75	17.0	22.6	29.95	39.25	49.3
App. Hp.	3.15	4.55	6.05	8.025	10.52	13.21
Real Hp.	1.65	3.36	4.86	6.58	8.57	10.30
Brake Hp.	1.19	2.68	3.83	5.00	5.94	6.29
Lbs. Torque	7.02	16.38	24.18	32.5	41.35	47.6
Slip r. p. m.	20.6	41.75	62.7	91.0	139.2	197.0
Motor speed	881	660	839	811	762	705
Power Factor	52.3	73.9	80.4	82.2	81.3	77.9
P. F. Check	52.4	73 3	80.4	82.1	81.5	78.0
App. Eff.	37.5	58.8	63.3	62.3	56.5	47.5
Real Eff.	71.5	79.75	78.85	76.0	69.2	61.0

	(7) The real and apparent efficiencies are found in the usual way, by taking the ratio of output to input.	(7) Max. torque = ordinate on O_c to circle of torque — ordinate of C_0. Starting torque = ordinate of T_L — ordinate of C_0.	(7) Pull-out torque = $(6.73 - 0.3)\,a$ = 50.1 lbs = 1.54 x full-load torque. Starting torque = $(4.30 - 0.3)\,a = 31.2$ lbs. = 0.96 x full-load torque.
NO-LOAD LOSSES	(8) The ordinate of C_0 represents the no-load loss (iron loss, friction and $i_0^2 r_1$), which is assumed constant at all loads and should be subtracted from the ordinates of torque and output.	(8) The total no-load current consists of a magnetizing component and of a power component (AC and CC_0), and by the amount of this latter the useful torque and output are diminished.	(8) Ordinate of $C_0 = 0.3a$. correction for torque and output.
MAGNETIZING AND LEAKAGE	(9) For any primary current, as AC_1, draw the ordinate of C_1 to the base line AB at L_1. Then: per cent. magnetizing current $= \frac{AC}{AC_1}$; per cent. leakage current $= \frac{AL_1 - AC}{AC_1} = \frac{CL_1}{AC_1}$.	(9) Working component of $AC_1 = L_1C_1$; wattless component AL_1. This latter consists of two portions: magnetizing—AC, and leakage, CL_1.	(9) At full-load—abscissa of $C_1 = 3.41a$; abscissa of $C = 1.97a$; length $AC_1 = 5.99a$. Therefore, per cent. magnetizing $= \frac{5 \times 1.97}{5 \times 5.99} = 32.9$; per cent. leakage $= \frac{5 \times (3.41 - 1.97)}{5 \times 5.99} = 24.05$.



THE HEYLAND DIAGRAM

CABLE SPLICING

By W. BARNES, Jr.

THE first and most important thing in the splicing of cables is to get the strands thoroughly clean. Where the rubber in the insulation of a cable has worked its way down into the strands and adhered to them, the best and in the end the quickest way to remove it, is to pass the hot flame of a gasoline torch over the strands and wipe each strand separately with a piece of waste. This should be done quickly before the rubber hardens.

The next consideration is a plenty of strong, clean binding wire. The binding wire for the average cable joint should be annealed bare copper wire at least No. 16 in size. If this wire is in a form convenient to use much time and trouble will be saved. One of the best ways to keep binding wire is to wrap it on a stick about eight inches long, one inch in diameter for soft wood and one-half inch in diameter for hard wood. Not more than six layers of wire should be wrapped on one stick nor should it be wrapped within one and a half inches of the ends. This will allow a good hand hold when making a splice; also it will prevent the wire slipping off the ends and becoming entangled. It is advisable to place the stick in a lathe and wind the wire on in even layers. If a lathe is not to be had one end of the stick may be made to fit the cluth of an ordinary brace, the other end to fit a small hole in the side of a bench. By fastening one end of the wire on the stick and turning the brace two men can wrap the wire almost as well as on a lathe. Much time is often lost by attempting to wind a wire stick by holding it in the hands. Fig. 1 shows a stick of binding wire ready for use.

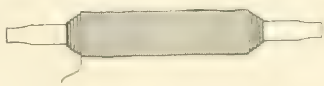


FIG. 1—STICK OF BINDING WIRE READY FOR USE

In splicing a cable where the strands are already free from dirt a neat job is obtained by using a sleeve. This sleeve may be either a brass or a copper tube. It should be a little larger than the wires in the cable and from 1-16 inch to 1-8 inch thick, according to the size of the cables to be spliced. The tube should be tinned before using. If acid is to be used it need not be applied until the

sleeve is in place. If paste is to be used the two ends of the cable should be thoroughly covered with it before the sleeve is put in place. Fig. 2 shows the cable prepared for the sleeve. Fig. 3 shows the sleeve in place with adhesive tape on the ends to retain the solder and paste or acid while the splice is heated. Two holes are shown in the top of the sleeve through which the acid or paste (when hot) is run. The solder is poured in at one of the holes until it shows signs of running out at the other hole. If the whole splice is kept hot with a blow torch, the solder will thoroughly penetrate every crevice. The sleeve should be filled up so that when the joint is cold the solder will be flush with the hole. The joint should not be disturbed in the least until it has cooled clear through, which may be some little time after the solder hardens at the holes. In a cable of large size it is advisable to have from four to six holes in the sleeve.

FIG. 2—CABLE ENDS PREPARED FOR SLEEVE SPLICING

FIG. 3—SLEEVE SPLICE SHOWING ADHESIVE TAPE AT EACH END OF THE SLEEVE

Okonite tape should be used in insulating the finished splices except for the last one or two layers where common adhesive tape may be used. In splicing lead-covered cable the outside lead sleeve is slipped over one end before the cables are put together. After the splice is made as much tape is applied on the joint as possible and then the lead sleeve is put in place. The two ends of the lead sleeve are to be wiped in the same fashion as a plumber makes a lead pipe connection.

A B

FIG. 4—ENDS OF CABLE PREPARED FOR SPLICING.

When a sleeve is not at hand, quite as neat and compact a joint can be made as follows: Remove the outside strands of one end of the cable as shown at A, Fig. 4. The other end at B has the core removed. Fit these two pieces together and wrap as shown in Fig. 5. But the binding wire must be put on good and tight if you want as good a job as a sleeve connection gives.

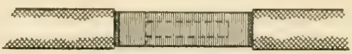


FIG. 5—FINISHED SPLICE

The splices shown in Fig. 3 and Fig. 5 are most frequently used on lead-covered cables, and as cables of this kind usually lie

in very small spaces and are often fished through close fitting conduits, their cross section cannot be greatly increased. This point is important.

Where it is not important to make the joint small and especially where the cable is subjected to a strain, a good and inexpensive joint may be made as shown in Figs. 6, 7 and 8. Fig. 6 shows the strands after they have been turned back. The ends should be bound with wire just back of the points where the strands are turned. See Fig. 6. Fig. 7 shows the splice with a portion of the strands in place. In making a splice of this kind, the strands should be put in place, one at a time, alternating from each cable. The strands should be made as straight as possible.

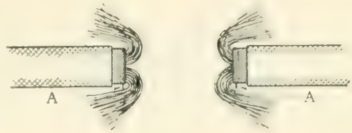


FIG. 6

After all strands are in place the joint should be tightened by several turns of heavy wire before the No. 16 or No. 14 binding wire is applied. The heavy wire may be removed when a large portion of the binding wire has been put on.

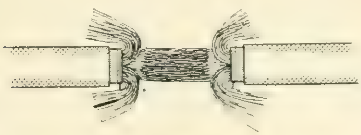


FIG. 7

Fig. 8 shows a complete joint of this kind wrapped and ready for soldering. If a torch is applied care should be taken that the binding wire is not burnt and that none of the solder remains on the surface to increase the size of the joint.

It often becomes necessary to tap a cable. Fig. 9 shows a tap on a cable ready for soldering. The binding wire should be applied the same as in the case of a splice. It will be noticed that the wires are distributed over the two sides and top of the cable. This secures a compact, neat and reliable junction.

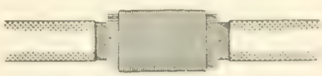


FIG. 8 CABLE SPLICE

The splices shown in these sketches may be used on any size of cable from 100,000 circular mills to 2,000,000 circular mills. On a cable of 100,000 circular mills the sleeve should be at least four inches long. If binding wire is to be used the joint should be wrapped for at least four inches. A cable of 2,000,000 circular mills should have a sleeve of 16 or 17 inches. If it is wrapped with binding wire it should be wrapped for the same distance.

In work which presents so large a variety of little problems, and in which actual experience counts so much, a few things not to do are well worth remembering.

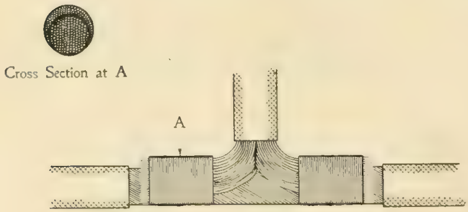


FIG. 9

Don't try to solder unless the cable is clean and a quantity of acid or paste is convenient.

Don't put binding wire on a joint in a haphazard manner. Put it on even and tight.

Don't try to handle more than one strand of a cable at a time and put that strand in the desired place before the next one is picked up.

Don't cut into the outside strands of a cable in removing the insulation.

Don't burn the binding wire on the outside of the splice.

Don't leave rough solder in the splice when it is cold.

SHOP EXPERIENCE

ITEMS FROM THE NOTEBOOK OF THE APPRENTICE

OIL FOR OIL-SWITCH WORK

THE requirements of oil for oil-switch work are very similar to those for oil transformers. Oil having a very low cold test may be desirable for use in switches which are intended for out-door work, but as this use is comparatively small at the present time this point need not receive consideration in connection with the general application of oil to oil-switch work.

The more fluid the oil for transformer work the more rapid will be the cooling action of the transformer on account of the more rapid circulation of the oil in the transformer tank. In switch work a more viscous oil seems to give better results, possibly on account of the fact that it is not so easily displaced by the arc as by the lighter oil. Otherwise the requirements are exactly the same for both transformer and switch work.

ACTION OF WATER-PROOFING COMPOUNDS IN TRANSFORMERS

In many transformers water-proofing compounds are used which may or may not be soluble in the oil in which the transformer is immersed. These water-proofing compounds are neces-

sarily good insulators. The materials used may have either an asphalt, coal tar or linseed oil base. When asphalt or coal tar base compounds are used they are always somewhat soluble in oil, especially when the oil is hot. Compounds having a linseed oil base, when thoroughly dry, are practically insoluble in mineral oil. When large quantities of water-proofing material, with asphalt or coal tar as a base, are used in transformers, the compound resulting from the combination of the water-proofing material and the transformer oil may form a pasty mass, which will close up the ventilating spaces and consequently cause dangerous heating of the transformer due to the lack of ventilation. From an insulation standpoint there is no objection to the water-proofing compound being dissolved out after the transformer is put in service, provided the design is such that the ventilating spaces which are essential to the cooling of the transformer are not filled up. Any compound which is soluble in mineral oil should not be depended upon for cementing parts of the transformer or for closing spaces when this compound may be dissolved out by the oil later. The linseed oil compounds are water-proof in the sense that they will not allow water to pass through where there is an unbroken film, but they are not water-proof in the same way that asphalt and coal tar base compounds are water-proof, i. e., they are not water-repellant. When transformers are treated with linseed oil compounds more care must be taken to prevent the absorption of moisture than when the other class of compounds is used.

EDITORIAL COMMENT

The New Epoch The curves given by Mr. Mershon in a recent paper before the American Institute of Electrical Engineers entitled, "The Maximum Distance to Which Power Can Be Economically Transmitted," cover a field which is as much beyond our present realizations, as the electrical transmission of to-day exceeds that of ten years ago. Generally speaking we have added a cipher to the distance of transmission, the voltage and the power which were common ten years ago. Distances of two or three to ten or fifteen miles have increased to twenty or thirty or one hundred to one hundred and fifty miles, voltages of 2,000 to 6,000 have increased to 20,000 to 60,000 and the units have gone up from thousands of horsepower to tens of thousands. In determining the limiting distance to which power can be economically transmitted,

Mr. Mershon contemplates voltages measured by the hundred thousands and distances running up to 500 and 600 miles and units of power ranging from 25,000 to 500,000 kw. In the curves which he gives the shortest distance considered is 100 miles. There is at present very little power transmitted to that distance. The lowest voltage which he considers is 75,000 volts, which is beyond present practice. The smallest unit of power shown in his curves is 25,000 kw., which is exceeded by the output of very few stations now in operation, and the largest amount of power contemplated, which is 500,000 kw., is far beyond the present electrical consumption in New York City with its great lighting and railway installations.

How imminent is the occupancy of this new field? Is the next decade to see the decimal mark moved one point further, as has been the experience of the past decade? What is the real significance of this tremendously rapid extension of the use of electricity? It is this, electricity is simply the conveyor and distributor of power, and it is *the application of mechanical power* which is the real underlying principle in modern industrial and commercial progress, and electricity prospers because it efficiently promotes this development.

In the activity of the present it is difficult to get a perspective view to determine the rate of progress and to observe the general course which things are taking—not only electrical development but engineering progress in general and its effect upon industrial, commercial and social life.

This general view is admirably presented in a small but remarkable book by the late George S. Morison, a noted civil engineer and a man of high attainments. In this book, "The New Epoch," * he points out that the manufacture of mechanical power has introduced a new force which is a greater factor in the progress of civilization than anything else which has occurred in historic times. Archeologists point out certain discoveries or inventions which mark epochs in the progress from savagery through barbarism to civilization. Mr. Morison presents the proposition that the past century has seen the opening of a new epoch, which is destined to produce changes even more remarkable than those which followed the ushering in of the epochs in prehistoric times and greater than any of the changes which written history records.

*The New Epoch; Houghton, Mifflin & Co., 75 cents.

To the young man who is entering upon an engineering career, especially to the electrical engineer, whose profession deals primarily with the application of power, this book should be read with especial interest. To all who are concerned with the underlying factors of modern times and who would seek the underlying cause for the changes which are taking place so rapidly about us, this book will likewise shed a flood of light. CHAS. F. SCOTT.

Induction vs. Synchronous Apparatus There are some controversies in electrical engineering which do not become settled. In some circumstances one machine or one method is superior, in other cases the other is best. Direct current versus alternating current for general service; single versus two or three-phase circuits; high versus low frequency; synchronous versus induction motors; rotary converters versus motor-generators; direct-current versus single-phase railway systems, admit of no universal solution. Circumstances and conditions are important factors and they vary widely. In most cases the controlling elements are the operating or service conditions—the practice rather than the theory.

A considerable part of the power generated by the electric power stations installed in recent years is in the form of polyphase alternating current, and a considerable portion of this current operates motors and rotary converters. These translating devices employ either of two principles of operation—they are either induction or synchronous. The synchronous machine has direct-current field excitation and the speed is independent of the load; the induction machine has no direct current and its speed varies with the load. The two types are different in design, they are also quite different in their features of operation.

Several cases have come to notice recently in which information on this general subject was desired and we therefore reprint an article by Mr. Scott, of which the original is not available to many of our readers. The statements of three years ago require little or no modification now. Very few synchronous motors of small size are now made, and even for large outputs, the induction motor is used very largely. Induction motors are employed on the largest and longest transmission systems, and in at least one case where thousands of horse power are involved, including many motors ranging from 400 to 700 hp., all of the motors are of the induction type.

The apparent conclusion to be drawn from Mr. Scott's comparison of motors is that the induction motor is the simplest and that in general it should be chosen unless the voltage adjustment which can be made at the receiving end of the line by means of the field current of the synchronous motor, or the reduction of lagging current which can be effected by causing the motor to take a leading current, are of sufficient importance to be controlling factors in the choice of the type of motor.

PERSONAL MENTION

Mr. C. M. Masson is now one of the operating engineers of the Kern River Power Company, whose generating equipment consists of five 3,000 kw. steam turbine driven alternators. Mr. Masson is located in the generating station at Borel, Kern county, Cal.

Mr. G. Skog is now connected with the construction department.

Mr. E. Y. Wootten is at the Atlanta office.

Mr. J. W. Sweeney is installing a 6,600-volt alternator at Shawinigan Falls, P. Q.

Mr. F. B. H. Paine, who has been connected with the Electric Company in various capacities since 1886, having been recently manager of the export office in the sales department of the company, has resigned to accept the position of general manager of the Niagara Construction Company, Limited. This company is installing the plant of the Ontario Power Company at Niagara Falls.

Mr. B. C. Shipman has been appointed district engineer at Baltimore.

Mr. E. T. Freeman, lately district engineer at Baltimore, is on his way to Snoqualmie Falls Power Company to put a 5,000 kw. alternator in the generating station, which is excavated in solid rock, 250 feet underground.

Mr. H. Gilliam, lately in charge of the engineering work at the Louisiana Purchase Exposition, has been appointed district engineer at New York. Mr. C. H. Smith succeeds Mr. Gilliam as district engineer at St. Louis.

Mr. J. H. Henderson has completed his apprenticeship course and is now in the construction department at Chicago.

Mr. W. A. Rossell, of the construction department, has been assigned to the sales department at Syracuse, N. Y.

WITH THE PUBLISHERS

More than a thousand subscriptions came to us last month and every day brings forty to fifty more. While these are largely renewals, still the number of new subscriptions is large. We owe these chiefly to the custom of some of our friends of showing THE JOURNAL to those who have not seen it. The practice of this commendable habit by all subscribers will enable us to attain a larger circulation and it will help us to make a better magazine for you.

An index for binding in Vol. I. of THE JOURNAL has been printed and will be mailed to every subscriber on request. It will also be sent to your friends who want an idea of what is in THE JOURNAL.

HORIZONTAL LIGHTNING FLASH TAKEN FROM THE UNIVERSITY CLUB, SALT LAKE CITY, BY C. A. GAINES. THE BUILDING WITH THE SPIRES IS THE MORMON TEMPLE. THE DISTANCE OF THE FLASH WAS SO GREAT THAT THE THUNDER WAS INAUDIBLE

THE
ELECTRIC CLUB JOURNAL

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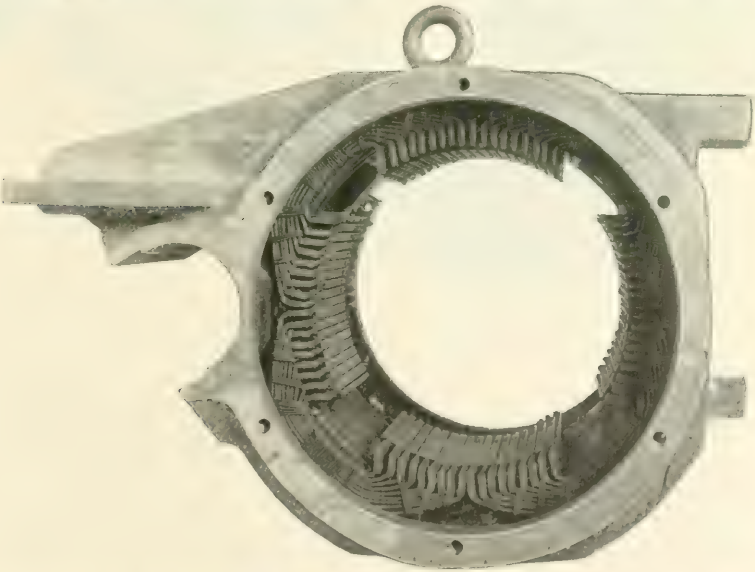
THE ALTERNATING-CURRENT SERIES MOTOR

By F. D. NEWBURY

THE NEUTRALIZING FIELD WINDING

THE first alternating-current series motors built for commercial railway service were designed for the low frequency of 16 cycles and without the neutralizing field winding. During the experimental tests made on these motors at the Westinghouse works the neutralizing field winding was added and it was

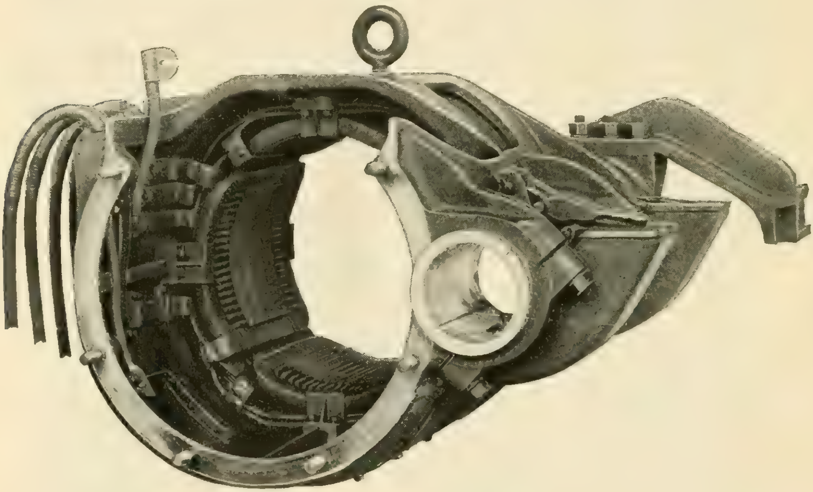


WESTINGHOUSE SINGLE PHASE RAILWAY MOTOR SHOWING THE NEUTRALIZING FIELD WINDING. THE MAIN FILED WINDINGS ARE HERE REMOVED

found that with the addition of this winding the operation was practically as good at 25 cycles as it had been without the winding at 16 cycles. Later alternating-current railway motors have

been, without exception, provided with the neutralizing field winding and have been designed for operation at 25 cycles. The feasibility of operation at this standard frequency with its advantages of standard generating and transforming apparatus is largely due to the neutralizing field winding. The effect of the winding to which its value is due is the neutralization of the self-induction of the armature, improving to this extent the power-factor of the motor. It will be of interest to see why the armature self-induction can be counteracted and to see how it is done.

The power-factor of the motor, just as of any other electric circuit, depends on the relative values of the inductive and energy



WESTINGHOUSE SINGLE-PHASE RAILWAY MOTOR SHOWING BOTH THE NEUTRALIZING WINDING AND THE MAIN FIELD WINDING IN PLACE

components of the total voltage required for the operation of the motor. To improve the power-factor the energy component must be increased or the inductive component must be decreased. For any given load the energy component can be increased only by increasing the losses. This method of increasing the power-factor is obviously inadmissible on the score of efficiency, although it has been seriously advocated. The second method, that of decreasing the inductive component, is, however, desirable and feasible.

Consider first the motor without the neutralizing field winding. There are two sources of self-induction in the motor circuit, the field winding and the armature winding. The self-induction of

the field winding is an inevitable consequence of the production of power by the motor. It is due to the same magnetic flux by means of which the counter e.m.f. in the armature is generated. This self-induction in a given motor cannot be reduced without reducing at the same time the power developed by the motor. It can be reduced, however, and the power-factor considerably improved by reducing the air-gap, but good railway practice requires a certain size air-gap for mechanical reasons. The air-gap in the alternating-current railway motors is made equal to that used in direct-current motors of similar capacity, and for the same power-factor, the air-gap of the series motor may be approximately twice the size of that of the induction motor, with its closed secondary.

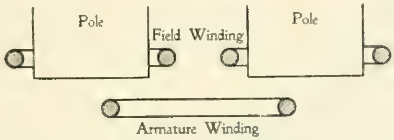


FIG. 1—DIAGRAMMATIC ARRANGEMENT OF WINDINGS ON AN ALTERNATING-CURRENT SERIES MOTOR HAVING NO NEUTRALIZING WINDING

The self-induction of the armature winding is, on the contrary, due to magnetic flux that serves no useful purpose; it is not essential to the operation of the motor. Decreasing the self-induction of the armature winding is then the best available method for increasing the power-factor.

For a moment consider the direct-current series motor. It is well known that through the action of the commutator the armature winding in its magnetic effects is equivalent under all conditions of operation to a number of stationary coils, whose positions are determined by the position of the brushes. With the brushes in their usual position one of these equivalent stationary coils is located as shown diagramatically in Fig. 1.

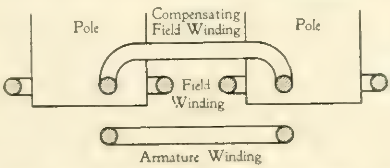


FIG. 2—ARRANGEMENT OF WINDINGS ON AN ALTERNATING-CURRENT SERIES MOTOR WITH NEUTRALIZING WINDING

This property of the motor is not changed in the least when alternating current is used in place of direct current, so that Fig. 1 represents the equivalent location of the windings in the alternating-current series motor. With this equivalent position of the armature winding established it is easy to see that the armature self-induction can be neutralized by adding a stationary winding to the motor so placed and

connected in the motor that it produces a magnetic field approximately equal in amount and opposite in direction to the magnetic flux generated by the current in the armature-winding. The position of this winding in the motor is shown in Fig. 2, and its connection in the circuit is shown in Fig. 3. From the relative positions of the different windings, as shown in Fig. 2, it is seen that neither the armature winding nor the neutralizing field winding can have any inductive effect on the field winding, *i. e.*, there will be no mutual induction between the field windings and the other windings.

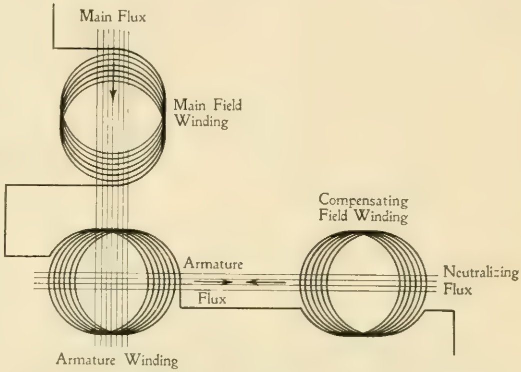


FIG. 3—DIAGRAM FOR CONNECTING THE WINDINGS OF THE SERIES ALTERNATING-CURRENT MOTOR

As actually constructed, the neutralizing winding is wound through slots in the poles and distributed in a number of slots in

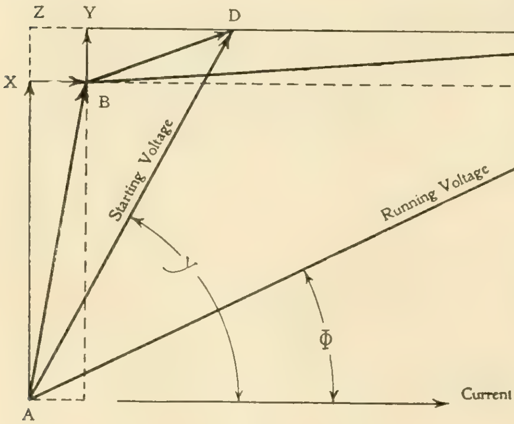
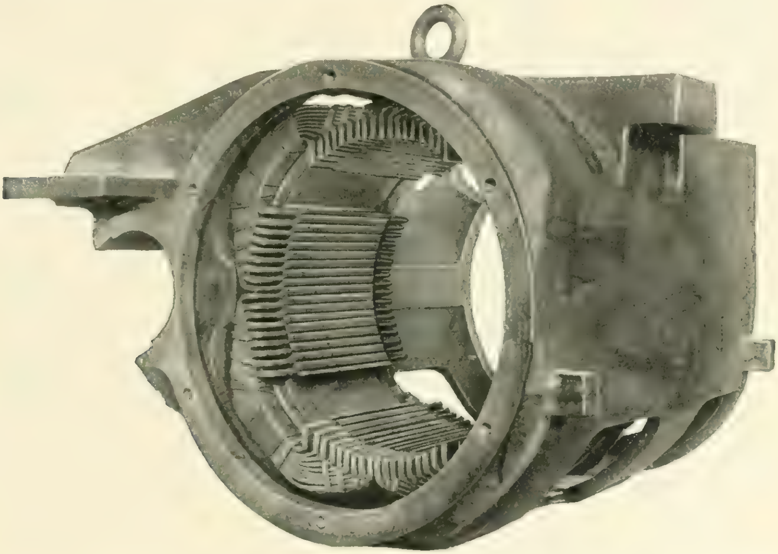


FIG. 4

order to approach the distribution of the armature conductors. This is shown very clearly in the accompanying reproductions from photographs of the new motors.

Just how the neutralizing winding affects the power-factor can be shown very nicely by the e.m.f. diagram. Fig. 4 is the diagram for the motor without this winding.

AB is the voltage across the field winding, made up of the inductive component AX used in overcoming the e.m.f. of self-induction of the field coils, and of the energy component XB used in supplying the losses in the field. BD is the voltage across the armature at start and is made up of the inductive component BY



WESTINGHOUSE SINGLE-PHASE RAILWAY MOTOR SHOWING THE NEUTRALIZING FIELD WINDING. THE MAIN FIELD WINDINGS ARE HERE REMOVED

and of the energy component YD, which in this case represents simply the electrical losses in the armature. Under running conditions the diagram is changed by the addition of the energy component DC of the armature voltage representing e.m.f. opposed to the counter e.m.f. generated by the armature. This increases the armature voltage to BC. At start the voltage required by the motor is AD and the power-factor of the circuit is the cosine of the angle γ. When the motor is running and developing the power represented by DC the voltage required is AC and the power-factor is the cosine of the angle ϕ. This same diagram is explained in greater detail in THE JOURNAL for February, 1904.

In Fig. 5 the voltage of the neutralizing winding is added. CM is the e.m.f. across the compensating field winding (neglect-

ing the small loss in this winding) equal and opposite to the inductive e.m.f. of the armature. The voltage across the motor terminal has been changed from *A C* to *A M* and the power-factor has been changed from the cosine of the angle Φ to that of the angle θ

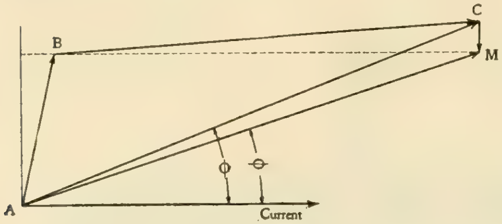


FIG. 5

From the consideration of the diagram, Fig. 5, without checking it with the actual operation of the motor, this question will probably arise: Why is it not possible to increase the compensation effect beyond that required by the armature, and so further improve the power-factor? This looks very easy on the diagram; but the diagram, however, is incomplete in one important respect; it does not take into account the location of the different sources of inductive e.m.f. In the motor it is impossible for the neutralizing field coils to neutralize more than the armature self-induction. No matter how great or how small the ampere turns of the neutralizing field coil, the self-induction of the motor circuit will be the difference between the self-induction of the armature and of the neutralizing field winding added to the self-induction of the main field winding.

PROTECTIVE APPARATUS

By N. J. NEALL

A Method of Investigating Lightning Arrester Operation

In the summer of 1902, The Utah Light and Power Company offered Mr. Percy H. Thomas, then of the Electric Company, an idle branch of its transmission line for experimentation with lightning and static disturbances. This branch, known as the Sandy Line, is some six miles in length and situated south of Salt Lake City in a valley which lies north and south and is bounded on both sides by mountains rising 2 000 feet or more above it, Fig. 1.

Charged clouds and storms passing east and west over these mountains exhibit a pronounced tendency to discharge and thus affect the many transmission lines below. The frontispiece in this issue shows beautifully a typical Utah storm occurring last season. The stroke passed from one side of the valley to the other—a distance of six to ten miles, and while plainly visible to the eye was said to have been inaudible.

The experimental work on this idle line—which was absolutely disconnected from the main lines and therefore without voltage—was limited to the placing of spark gaps between the line and the ground

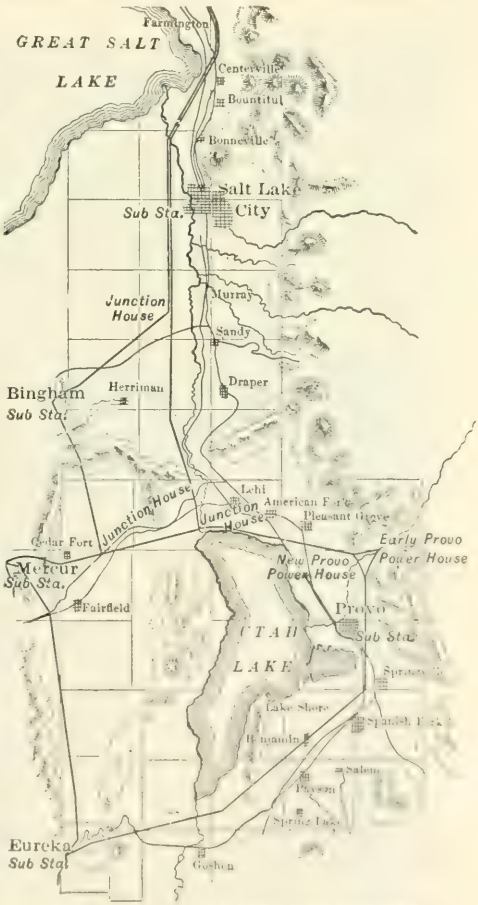


FIG. 1—SALT LAKE CITY AND VICINITY
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and the interception of a standard choke coil (such as is used with lightning arresters) in parallel with a spark gap, shown in

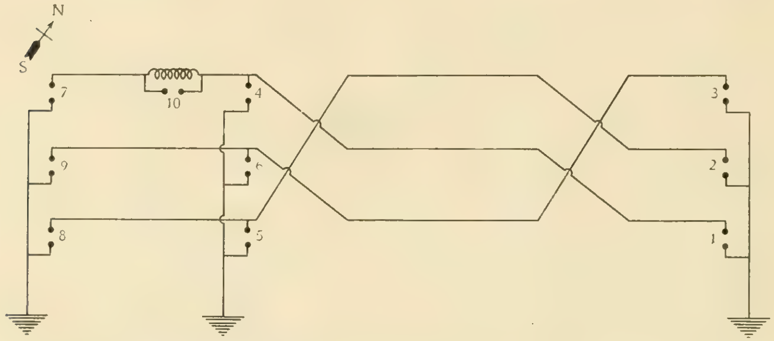


FIG. 2—DIAGRAM SHOWING LOCATION OF SPARK GAPS ON IDLE LINE

Fig. 2. The gaps were given various openings and tell-tale papers were inserted to note discharges. The line was watched closely for many weeks, papers being frequently inspected, especially after each storm.

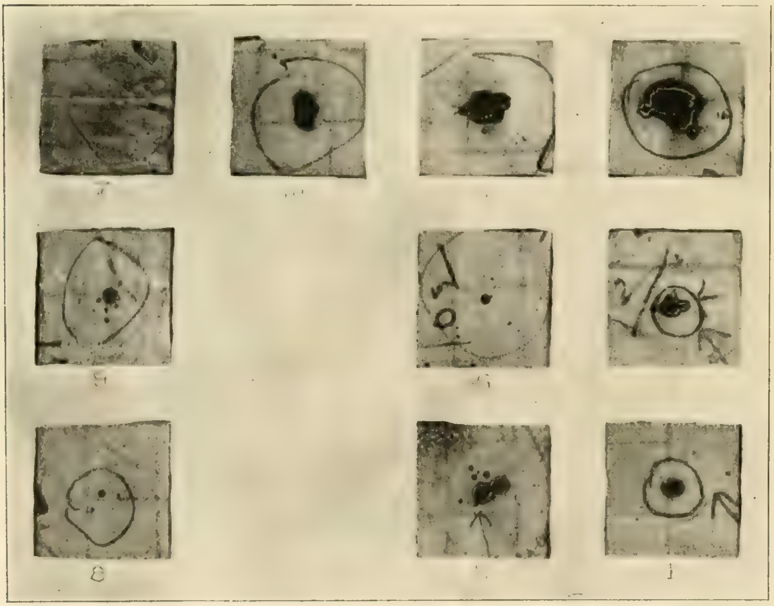


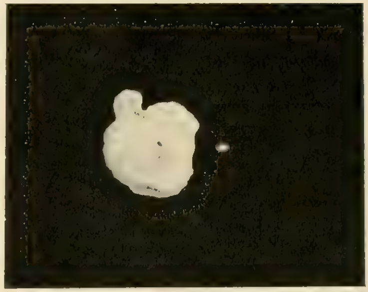
FIG. 3—PUNCTURED PAPERS REMOVED FROM THEIR RESPECTIVE GAPS SHOWN IN FIG. 2

About Sept. 1st a heavy stormed occurred, and the papers shown in Fig. 3 removed from this period, are not only complete, but highly interesting. The usual method of inspection for such records is to hold them up to the light, for often the punctures are so fine as to be otherwise almost invisible. In order that they may be described in print, the holes have been magnified and photographed in an ingenious way by Mr. C. E. Skinner of the engineering department, to whom the writer is very much indebted for the excellent illustrations. The holes have been grouped to correspond with the location of their respective gaps on the line as shown in Fig. 2.

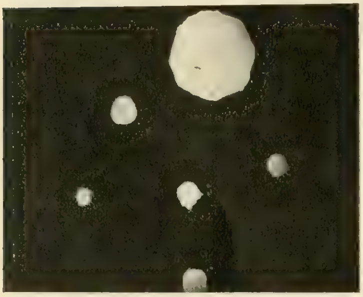
FIG. 4—PAPER AND ITS MAGNIFICATION SHOWING A DISCHARGE OVER A GAP OF 1.63 INCHES ON IDLE LINE. MAGNIFIED 19 TIMES

Possibly the most interesting paper was obtained from gap number 10, in shunt with the choke coil, showing the passage of the discharge from one end of the line to the other. It is believed that this line was not struck by lightning and that the punctures, therefore, represent the release of free induced charges. It will be observed that the papers at one end of the line have larger holes than at the other. This may arise from several causes, probably from several discharges during the storm, all such passing in the same direction, as would be expected, since the line lies across the path of the clouds. It is to be noted, moreover, that some comparatively large gaps were punctured. The equivalent voltage breakdown for such a setting as in the case of number 9 gap is

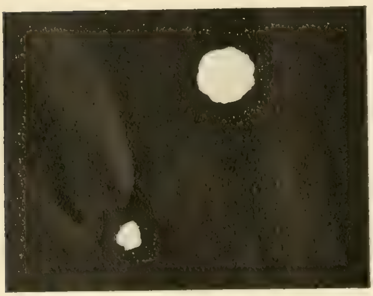
NO. 7—MAGNIFIED 15 TIMES. SHOWS DETAIL ONLY



NO. 10—MAGNIFIED 10 TIMES. SHOWS COMPLETE PAPER



NO. 9—MAGNIFIED 10 TIMES. SHOWS DETAIL ONLY



NO. 8—MAGNIFIED 13 TIMES. SHOWS COMPLETE PAPER

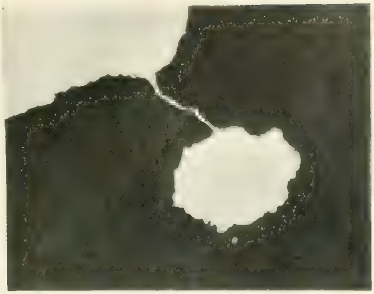
MAGNIFICATION OF PAPERS SHOWN IN FIG. 3

30 000-40 000 volts. A paper, Fig. 4, taken from the same line in June, 1903, shows a puncture over a gap at approximately 1.63 inches.

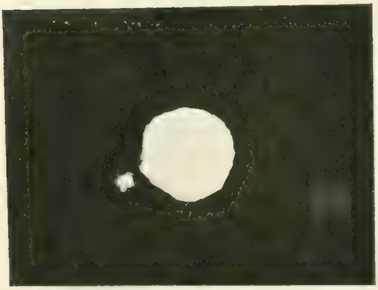
The photographs do not show easily the almost total absence of charring around the edge of the puncture, a condition which seems to be typical of a static discharge. Some of the smaller holes were absolutely without current trace—the large holes show a very slight browning. The important information in this case was the substantiation of the theory of induced atmospheric charges, the exceedingly high potential thereby imposed on the lines and the value of the gaps to earth to relieve this strain.

These records, moreover, throw interesting light on the meaning of papers which may be likewise placed in lightning arresters in commercial service. The placing of tell-tale papers in lightning arresters in order to

NO. 4—MAGNIFIED 5 TIMES. SHOWS COMPLETE PAPER



NO. 3—MAGNIFIED 22 TIMES. SHOWS DETAIL ONLY



NO. 6—MAGNIFIED 13 TIMES. SHOWS COMPLETE PAPER

NO. 2—MAGNIFIED 13 TIMES. SHOWS COMPLETE PAPER

NO. 5—MAGNIFIED 4 TIMES. SHOWS COMPLETE PAPER

NO. 1—MAGNIFIED 14 TIMES. SHOWS COMPLETE PAPER

MAGNIFICATIONS OF PAPERS SHOWN IN FIG. 3

obtain a record of their operation is not a new idea, but until one year ago it was not taken up seriously. Many station operators recognize clearly the advantage and necessity of metering their output, but very few think to apply the same idea to their protective apparatus.

Much can be done in the laboratory, but the real test of the lightning arrester must be made in service. The materials necessary are light weight bond papers of uniform texture, which should be inserted in the gaps to be investigated, and so shaped as to make it impossible for a discharge to pass without puncturing them. Each arrester on the system should have several of these papers,

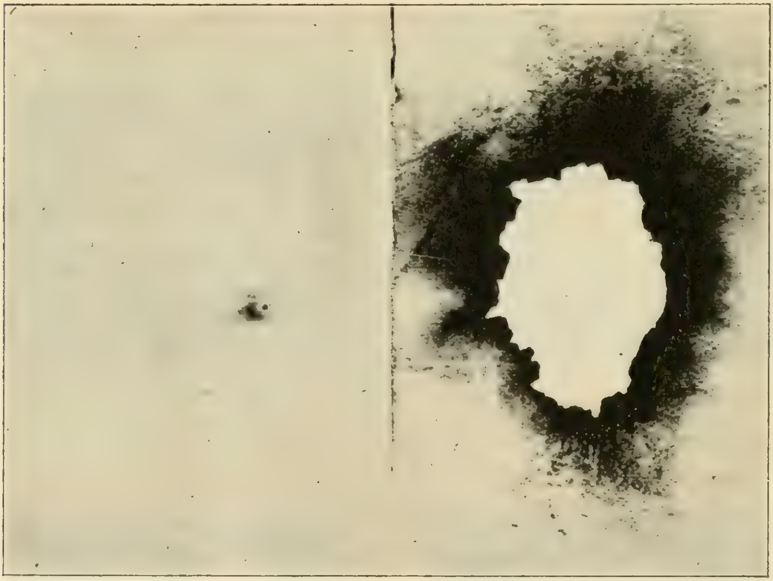


FIG. 6—FULL SIZE FIG. 5—FULL SIZE
TWO DISCHARGES FROM SIMILAR ARRESTERS PROTECTING SYNCHRONOUS APPARATUS

carefully dated, marked with the location on the line and of sufficient size for any remarks as to the particular events registered thereon by a static discharge. The papers should be removed regularly from the gaps except in times of disturbances, when they should be removed immediately after the storm.

It is obvious that if a file of these returns be kept, the operator of the plant can determine many interesting and valuable things as to the behavior of his line as a whole.

It is, of course, important that local geological and atmospheric conditions be well known. It should also be kept distinctly

FIG. 7—A PAPER AND ITS MAGNIFICATION SHOWING PURE STATIC DISCHARGE. MAGNIFIED 20 TIMES

in mind that, in general, lightning arresters on a line are affected by three main disturbances, viz., induced charges from lightning, short circuits, and grounds, both steady and intermittent. Switching

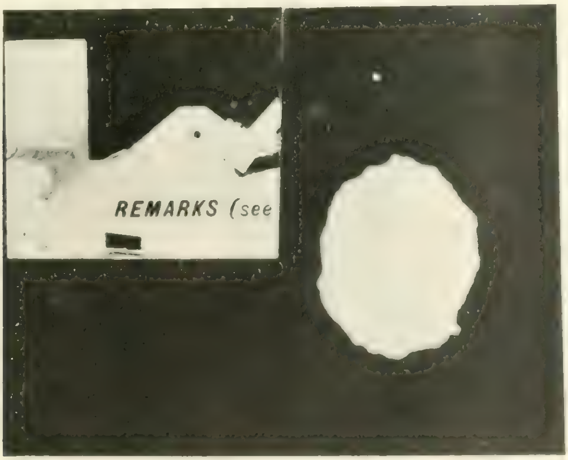


FIG. 8—PAPER AND ITS MAGNIFICATION FROM THE SERIES GAPS OF A LOW EQUIVALENT ALTERNATING CURRENT ARRESTER. MAGNIFIED 30 TIMES

and accidental resonance from line combinations will sometimes affect arresters. The strains on the protective apparatus then become, broadly speaking, of two kinds—electrostatic and electromagnetic. The former may occur without disturbing in any way the operation of the generating apparatus if the arresters are properly designed. The latter always arises as a secondary state, due to some action in the line, such as grounding.

It is not always easy to separate these effects in a collection of papers ken from a given line during one storm, but if carried through a season or two familiarity will enable the records to be judged quite accurately.

FIG. 9—PAPER AND ITS MAGNIFICATION FROM THE SHUNTED GAPS OF A LOW EQUIVALENT ALTERNATING-CURRENT ARRESTER. MAGNIFIED 45 TIMES

One of the worst conditions to be met by any lightning arrester obtains at a point where synchronous apparatus is being fed, for when the lightning arresters operate in such a way as to start

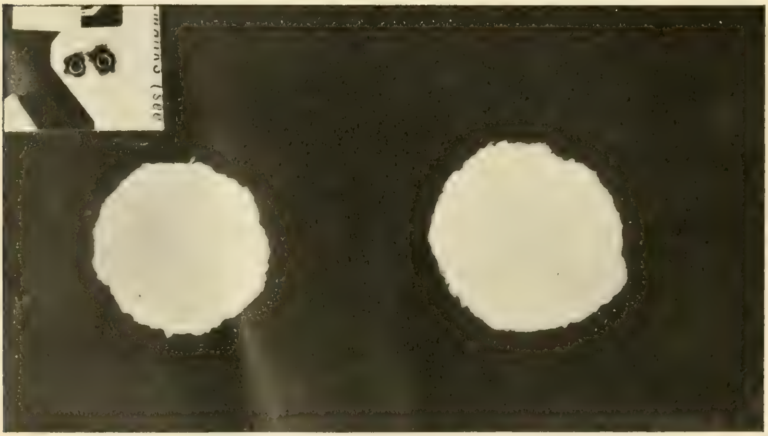


FIG. 10—PAPER AND ITS MAGNIFICATION REMOVED FROM THE SERIES GAPS OF A LOW EQUIVALENT ARRESTER IN CALIFORNIA. MAGNIFIED 12 TIMES

a short-circuit, the momentum of the synchronous apparatus makes it act like a generator and thus feeds and tends to hold it. The paper shown in Fig. 5 illustrates the result of such a condition.

Fig. 6 shows a discharge of the same type of arrester on the same service. From a number of observations it seems reasonable

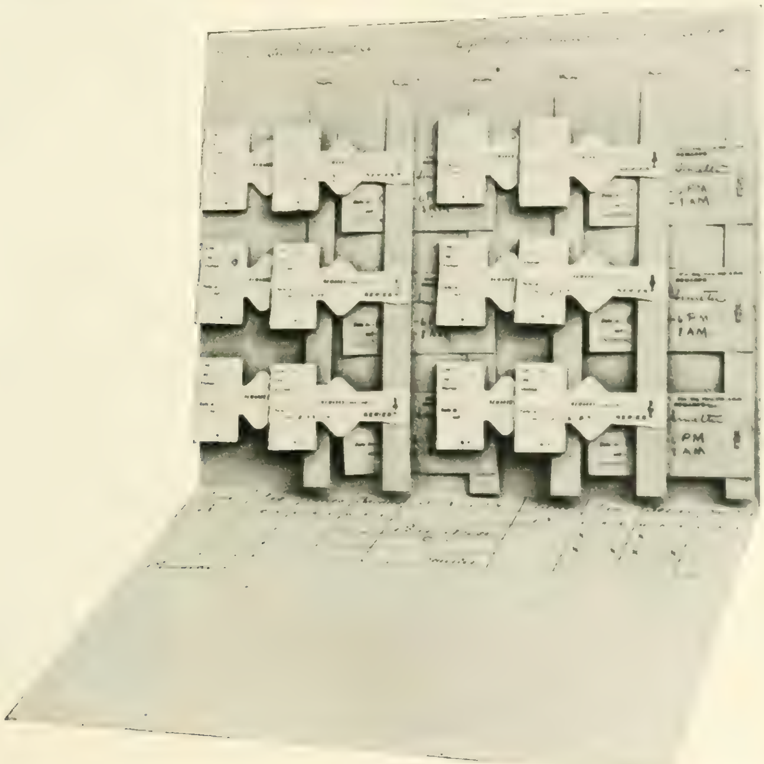


FIG. 11—A CONVENIENT FILE FOR RECORDS OF LIGHTNING ARRESTER OPERATION

to conclude that this great difference is due to the occurrence of the discharge at different points on the wave of the line current.

Records have shown that static disturbances can be released from a line with only very small holes to mark the passage, Fig. 7, although evidence is not lacking that a severe static discharge might leave a good-sized hole. Figs. 8 and 9 show two papers and their enlargement, taken from a low equivalent lightning arrester after a storm. They have an added interest in indicating that on this line, which is a straight away run of 30 miles from the power

house to the point of distributing, 3 000 feet above it, all the disturbances take place at the highest altitude, the power house arresters not even showing a surge, as might have been expected.

Fig. 10 shows an interesting paper obtained from California during a lightning storm.

Papers have been taken showing the effect of grounds on the line, short-circuit and switching.

As is obvious, such a system of investigation calls for the greatest care in filing the records—a suggested form is shown in Fig. 11, which holds the weekly record of a 6-wire, 30 miles, 25 000-volt transmission line with the papers arranged in such a way as to enable ready study of the sequence of the results. After conclusions are drawn the folder can be filed. Attention is called to the different shaped papers, which indicate that the method is applicable to any make of arresters.

Fig. 12 shows the papers intended for the low equivalent lightning arrester and the method of handling them.

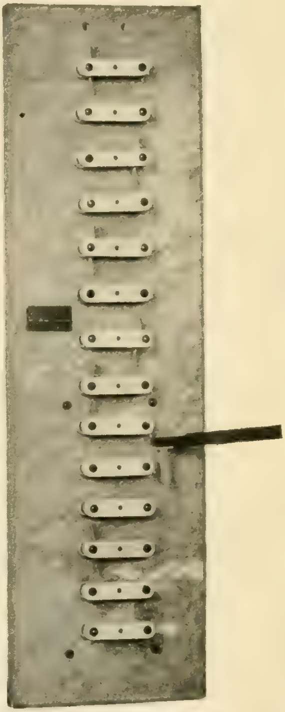


FIG. 12—METHOD OF PLACING RECORD PAPERS IN A LOW EQUIVALENT LIGHTNING ARRESTER

On looking over the history of lightning arrester development one must be strongly impressed with the fact that phenomena noted as long ago as 1859 have not been yet effectively allowed for. Take, for example, the case of the overhead grounded wire. Shaffner in his book, the "Telegraph Manual," in 1859, speaks of the apparent value of such a thing, but nothing has as yet been accomplished. It seemed to have been almost forgotten, when a few years ago its presentation before the American Institute of Electrical Engineers came with the force of novelty.

The method herein proposed has many defects, but has also great possibilities. Its chief fault lies in the necessity for the most faithful and patient gathering of papers. The station man must be depended upon to collect the records and must fully realize the importance of the observations and the necessity for avoiding any uncertainty as to facts. In this manner much valuable information can be obtained.

THE ECONOMICS OF HIGH VACUA AND SUPERHEAT IN STEAM TURBINE PLANTS*

By J. R. BIBBINS

MUCH uncertainty seems to exist at the present time concerning the relative value of high vacua and superheat. By the term relative is here meant—not a specific gain in steam consumption per se, but the *net saving to the power station at the coal pile.*

Is high vacuum and superheat *essential* to economical performance, and if not, why employ them? The reason is not far to seek:

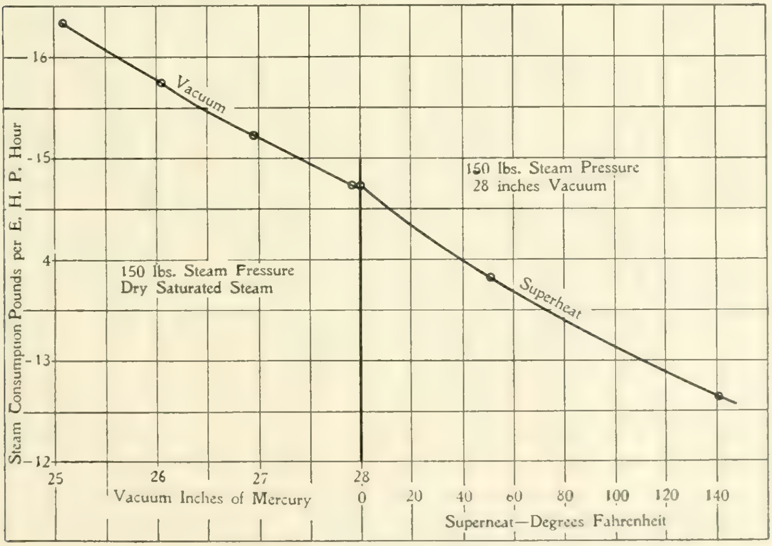


FIG. I—THE EFFECT OF VACUUM AND SUPERHEAT ON STEAM CONSUMPTION. TEST MADE ON A 1500 KW. TURBINE RUNNING AT FULL LOAD

In steam turbine work a distinctly new engineering problem has arisen in the shape of enormous steam velocities and correspondingly high surface and peripheral speeds. If left unchecked, the fluid friction results in much lost power and more or less rapid depreciation.

*Excerpt from a paper presented before the American Street Railway Association at St. Louis, 1904.

In some forms of turbines, more particularly the Parsons, these speeds have been reduced through compounding to such a point as to largely avoid the effects of steam friction. In all forms the loss from this and other sources may be greatly reduced by em-

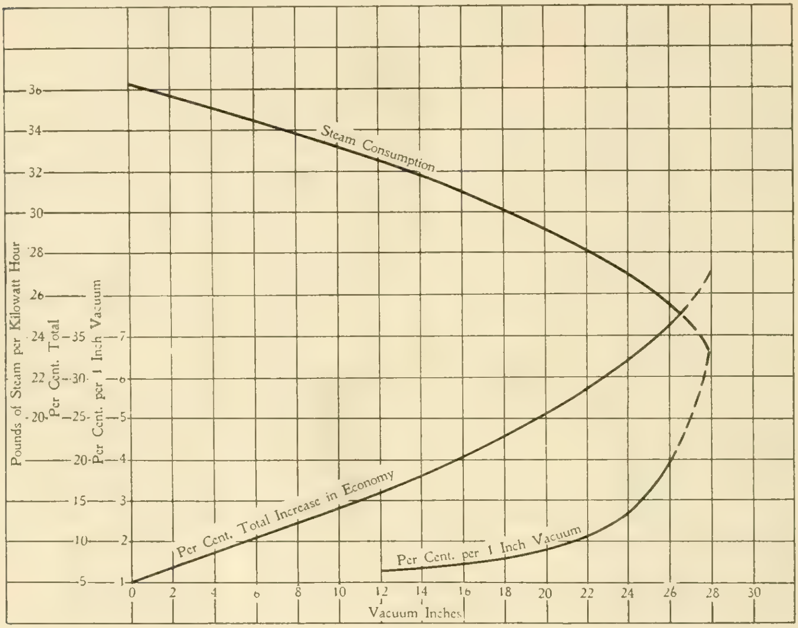


FIG. 2—RELATION OF VACUUM TO ECONOMY. TEST MADE ON A 300 KW. TURBINE. FULL LOAD. NO SUPERHEAT

ploying high vacuum and superheat. The former permits the low pressure section of the turbine rotor to move in a more rarefied atmosphere, and the latter serves to defer the "dew point" or beginning of condensation of steam during its expansion, thus eliminating to a large degree the detrimental effects of friction due to entrained moisture at high surface speeds.

But, although essential in some types, it is by no means so in the Parsons type of turbine, as is evidenced by the several installations working under 25 inches and 26 inches vacuum, with no superheat, but with excellent economy. The principal reason for the almost universal adoption of these economic expedients is the *ease* with which the turbine avails itself of the advantages arising. In a reciprocating engine, an attempt to expand below 5 or 6 pounds (abs.) back pressure might readily result in negative economy, the

increased friction and thermal losses overbalancing the small gain in steam consumption. The turbine, however, expands its working steam to within 1 inch of the barometer (0.5 pounds absolute pressure) with as great facility as to atmosphere, and the increase in bulk is scarcely comparable to that which would be unavoidable in a reciprocating engine. Moreover, the heat losses are infinitesimal and there results a clear gain in economy.

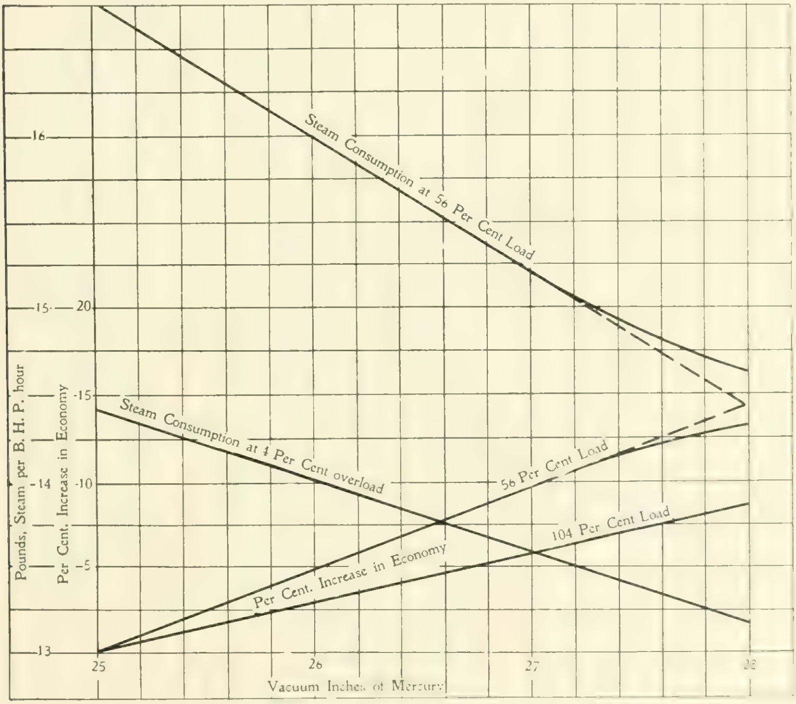


FIG. 3—THE RELATION OF VACUUM TO ECONOMY. NO SUPERHEAT. THE OBSERVATIONS AT 28 INCHES VACUUM WERE TAKEN FROM A SUBSEQUENT TEST UNDER THE SAME CONDITIONS

The nature of the saving due to vacuum and superheat has been clearly revealed by tests.

The effect of superheat on economy is fully as striking as that of vacuum. In Fig. 1 the steam consumption was reduced 23 percent.—from 16.45 to 12.66 pounds per e.h.p. at full load by raising the vacuum 3 inches and superheat 140 degrees.

Figs. 2 and 3 show the effects of vacuum alone. In the former the test covers vacua from 0 to 26.5 inches; in the latter from 25

inches to 28 inches. The drooping of the curve of steam consumption at the right, Fig. 2, clearly shows the relative advantages of the last few inches of vacuum. The curve, "Rate of increase per 1 inch of vacuum" shows this still more strikingly. At 21 inches vacuum the gain is but 1 per cent. per inch; at 26½ inches it is 3½ per cent.; and at 28 inches, 5½ per cent., the last point being, however, estimated.

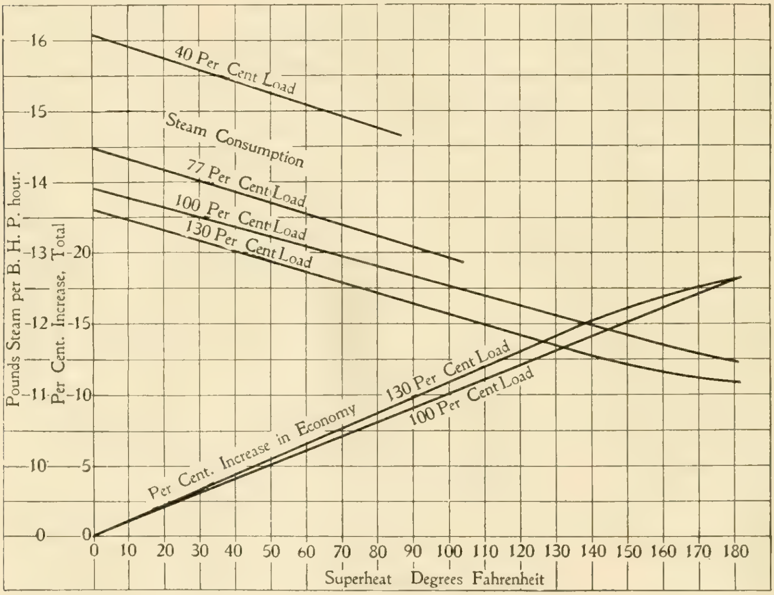


FIG. 4—THE RELATION OF SUPERHEAT TO ECONOMY. TEST MADE ON A 400 KW. TURBINE AT 28 INCHES VACUUM

A test upon a large Westinghouse-Parsons turbine between 25 inches and 28 inches, shown in Fig. 3, indicates somewhat different characteristics, viz: a proportional relation. This, however, might have been the case with the results, Fig. 2, if plotted to a larger scale and carried to the same limits. Here the benefit from vacuum at half load is considerably greater than at full overload, viz: 5 per cent. per inch in the one case and 3 per cent. in the other.

A series of tests* (Fig. 4) upon a 400 kw. turbine with superheated steam gives curves of a slightly different character but of close agreement with those of Fig. 1. The relation is a direct proportion, and a uniform gain of 10 to 11 per cent. per 100

*By Messrs. Dean & Main, Engineers, Boston.

degrees superheat is observed, this gain being practically the same at all loads, as the steam consumption lines are nearly parallel.

From these curves and other data on Westinghouse-Parsons machines it is apparent that, although wide variations exist, in round numbers 100 degrees superheat will insure a decrease in steam consumption of about 10 per cent., and 1 inch higher vacuum (between 25 inches and 28 inches) 3.5 to 4 per cent., depending somewhat upon the load.

Upon this assumption we may estimate the net saving resulting from the use of high vacuum. In Table I. three cases have been

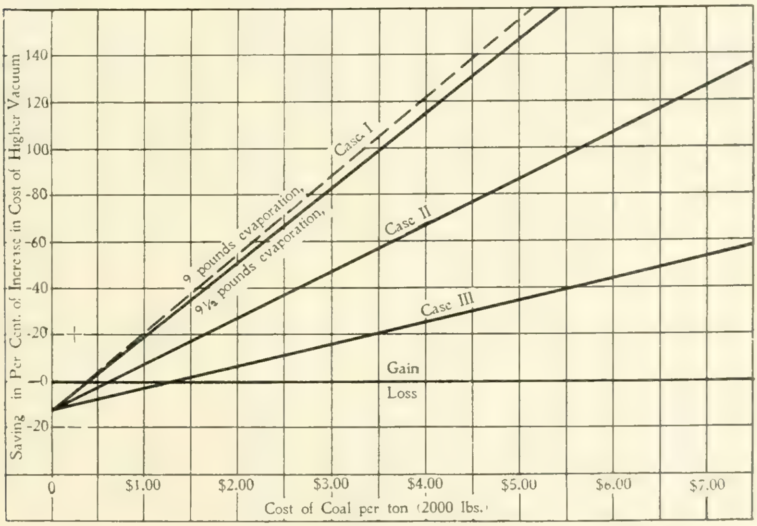


FIG. 5—THE RELATION OF THE NET SAVINGS, DUE TO HIGHER VACUUM, TO THE PRICE OF FUEL

calculated embracing possible or typical conditions of power plant service and cost of fuel. A 2 000 kw. plant has been chosen, containing two 1 000 kw. units. By raising the vacuum 2 inches—from 26 inches to 28 inches—a saving in coal results amounting to 3.5, 2.6 and 1.3 tons per day in the three respective cases. The extra cost† of high vacuum condenser equipment will be not more than $2.00 per kw. capacity or $4 000.00. Deducting the interest and depreciation on this investment from the several fuel savings a net saving is determined which represents an *interest rate* of 115

†This cost is being constantly reduced through improvements in condensing apparatus.

per cent., 27 per cent. and—3 per cent. respectively on *the increased investment in high vacuum.* The increased power requirements of the new equipment will presumably reduce these percentages by 1 to 5 per cent.* according to the price at which power is charged. Thus, assuming an increase in power input of 1 per cent., charged at a price of 1 cent per kw. hour, the net saving as shown by the table will be reduced by 3.3 per cent.,* 3.8 per cent. and .7 per cent. respectively. On the other hand, the percentages will be increased if the saving in cost of feed water is taken into consideration. Thus, at 10 cents per thousand gallons, which price prevails in New York, the percentage saving will be increased by 6.3 per cent., 3.9 per cent. and 1.6 per cent. in the respective cases. These estimates, although largely tentative, certainly point to high vacuum as an excellent investment where high plant economy is imperative.

The diagram, Fig. 5, embodies these relations in graphical form, and in addition covers for *each case* a wide range of fuel

TABLE I—RELATIVE ECONOMY OF HIGH VACUUM

CASE	I	II	III
Conditions of operation	Good Coal Continuous Service	Med. Coal Continuous Service	Poor Coal Day Service
Capacity plant.......Kw.	2,000	2,000	2,000
Daily run.......Hrs.	24	24	10
Yearly run.......Days	365	300	300
Average load.......Kw.	1,500	1,000	1,000
Price coal.......per ton (2000 lbs.)	$4.00	$2.00	$1.00
Evaporation (actual).......Lbs.	9½	8	7
Average economy...Lbs. water per Kw. hr.	23	22	22
Raise vacuum.......inches	26 to 28	26 to 28	26 to 28
Water saved per Kw. hour.......Lbs.	1.84	1.76	1.76
Water saved per day.......Lbs.	66,240	42,240	17,600
Coal saved per day.......Tons.	3.49	2.64	1.26
Gross saving per day.......	$13.96	$5.28	$1.26
Gross saving per year.......	$5,095.00	$1,584.00	$378.00
Extra cost of condenser.......	$4.000.00	$4,000.00	$4,000.00
Interest 5%, Depreciation 7½%.......	$500.00	$500.00	$500.00
Net saving per year.......	$4,585.00	$1,084.00	$- 122.00
" " " " Capitalized at 5%.......	$91,900.00	$21,680.00	$-2,444.00
**Net saving as interest on increased investment in 2 inches extra vacuum.......	114.9%	27.1%	-3.05%

*i. e. 1-5 percent. less than the percentages above given.

**Saving in cost of feed water and loss due to increased power requirements are not included in this estimate.

cost. With cheap coal there is evidently a point where the high vacuum *ceases to be a source of economy*. This is shown under the conditions assumed to correspond to coal at 40 cents, 62 cents, and $1.36 per ton respectively. On the other hand, with coal at $3.55 and $5.20 respectively, the annual saving in cases I. and II. is sufficient to *equal the original cost of the improvement*.

With superheated steam the same method of arriving at the net saving may be employed. At the present time the superheat usually specified in American turbine plants ranges in the neighborhood of 100 degrees Fahrenheit, which is easily within the limits of various forms of apparatus suited for mounting within the boiler setting in the path of the hot gases. A gross increase in economy of 10 per cent. is thus effected, and at an investment cost of fully 25 per cent. less than that for the 2 inches extra vacuum. Superheat, however, *cannot be obtained for nothing* and the net saving is evidently affected largely by the cost of heat supplied. In the case of the independent superheater this comprises fuel and stoking; in the case of the boiler superheater, the fuel value of heat delivered by the hot gases.

ELECTRIC RAILWAY BRAKING

PART VI

By E. H. DEWSON

FOUNDATION BRAKE RIGGING

THE truck leverage ratio should be kept as low as practicable; many makers supply levers proportioned 5 to 1, so that a one-pound pull at the upper end of the live lever gives a total of ten pounds at the brake shoes. This high truck leverage was desirable when braking was all by hand, but for the power brake it is much better to keep the proportion down to 3 to 1. With the high ratio a slight movement at the shoes gives considerable travel to the upper end of the live lever, which is liable to strike some part of the motor, thereby rendering the brake ineffective. To attain maximum efficiency with the automatic air brake the piston travel should be uniform throughout the train, as otherwise an unequal cylinder

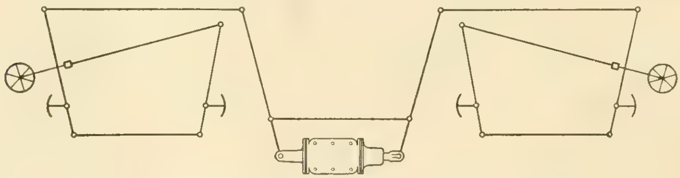


FIG. 16—THE STEVENS SYSTEM OF CAR BRAKE LEVERS

pressure will result on the different cars. Uniformity of piston travel is best attained by the use of an automatic slack adjuster. All the successful automatic slack adjusters for double truck cars take up the slack by drawing the upper ends of the live levers of the trucks closer together, thereby maintaining the same amount of shoe slack for the piston to take up when the brakes are applied. A type of adjuster very generally in use is illustrated on page 656, Vol. I., of the JOURNAL. With a total leverage ratio of 10 to 1 this adjuster will take up one inch of wear from the shoes provided the upper ends of the live levers have sufficient travel. In figures this means one inch for wear, one-quarter inch for shoe clearance and one-eighth inch for lost motion in journal boxes, a total of one and three-eighths inches movement for each shoe; with truck levers proportioned 5 to 1, the movement of the upper end of live lever

would be $13\frac{3}{4}$ inches, which would not be permissible. With 3 to 1 levers this movement is only $8\frac{1}{4}$ inches, which is within the limits of any standard truck.

Having determined the proper size of brake cylinder and chosen a truck with levers suitably proportioned, it is necessary to design the car body rigging to connect the two. In Figs. 16 and 17 are shown two designs well known to steam railroad car builders. In these systems, it will be noted that at both ends of the car the hand brake pulls against the air brake, which should be avoided whenever possible, as only one can be applied at a time. This means that the air brake must be completely released before the hand brake can be set, which is very inconvenient, if not dangerous, when the car is on a steep grade. If the air was partially applied when the hand brake was set, and later the air leaked off, the hand brake would be slack.

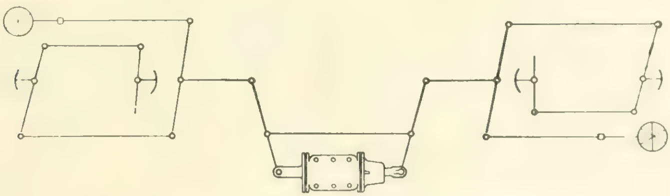


FIG. 17—THE HODGE SYSTEM OF CAR BRAKE LEVERS

In Fig. 18 is shown a modification of the Stevens system, which has been successfully applied to a great many electric cars. The same cylinder levers are employed for the purpose of dividing the force of the cylinder between the trucks, and at the same time multiplying it to such an extent that the desired resultant pressure on the wheel shoes will be obtained. The power of the hand brake, however, is applied from both ends through the point of application of the air power to the cylinder levers, consequently the two powers work together. This is an extremely important point to be observed when designing a gear which includes a slack adjuster that operates by changing the position of the fulcrum of the cylinder lever, as otherwise its action will render the hand brake ineffective. The multiplying lever is introduced to make it possible to apply the same brake power by hand as by air, which otherwise would be impracticable on account of the car not being wide enough for a sufficiently long hand brake lever.

In all of the above illustrated systems it will be noted that no

stress can be exerted on any wheel until all the shoes are bearing against their respective wheels. Also that, neglecting any differences due to the friction of joints, the braking forces are always divided in accordance with the proportions of the levers governing them. Such systems are termed *equalizing*, and none but equalizing system of brake rigging should ever be employed. No matter how accurately the slack of the different shoes may be adjusted in a non-equalized system, the instant the car is moved the relations of the different wheels and parts of the trucks to each other are varied sufficiently to render the proper distribution of the brake power impossible.

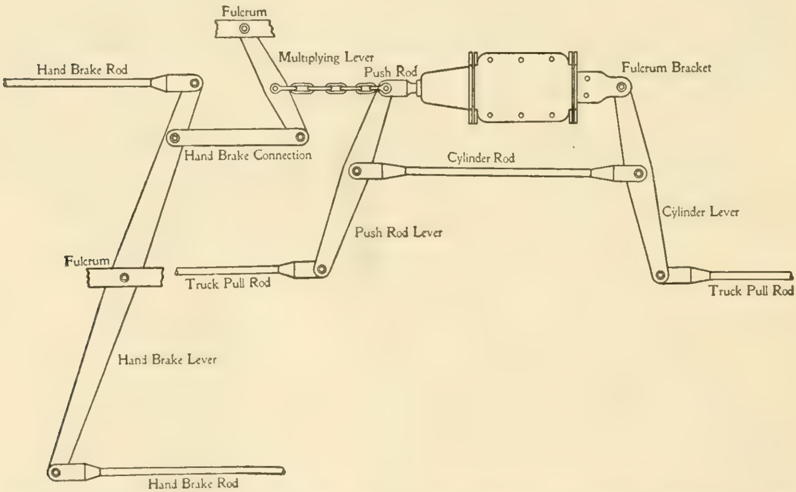
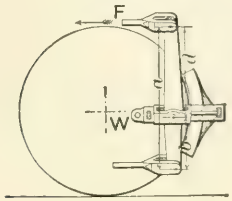


FIG. 18—A MODIFICATION OF THE STEPHENS SYSTEM OF BRAKE RIGGING. THE HAND POWER AND THE AIR POWER ARE APPLIED AT THE SAME POINT

In Fig. 19 are shown the three different forms of levers as applied to brakes, together with the formulae pertaining to each. These are all derived from the equation $F \times a = W \times b$, which is based upon the equilibrium of forces acting upon a lever in a state of rest, when F is the applied force, W is the delivered force and a and b the respective distances of the points of application of these forces from the fulcrum. Furthermore, the sum of the two forces acting at the ends must equal the force acting at the intermediate point, consequently when two of the forces are known the third may readily be determined. It is of utmost importance that the same units of force and distance be preserved throughout the cal-

culations, all forces being preferably expressed in pounds and all distances in inches, the latter invariably being measured from center to center of pins or pin holes.

The following practical example will illustrate the method of employing the above formulae in working out a brake problem.



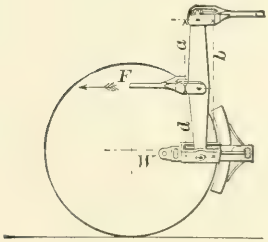
$$W = \frac{F \times a}{b}$$

$$F = \frac{W \times b}{a}$$

$$a = \frac{W \times b}{F} \text{ or } a = \frac{W \times d}{W - F}$$

$$b = \frac{F \times a}{W} \text{ or } b = \frac{F \times d}{W - F}$$

DELIVERED FORCE BETWEEN FULCRUM AND APPLIED FORCE



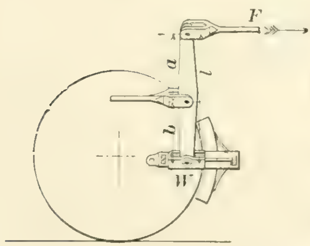
$$W = \frac{F \times a}{b}$$

$$F = \frac{W \times b}{a}$$

$$a = \frac{W \times b}{F} \text{ or } a = \frac{W \times d}{F - W}$$

$$b = \frac{F \times a}{W} \text{ or } b = \frac{F \times d}{F - W}$$

APPLIED FORCE BETWEEN FULCRUM AND DELIVERED FORCE



$$W = \frac{F \times a}{b}$$

$$F = \frac{W \times b}{a}$$

$$a = \frac{W \times b}{F} \text{ or } a = \frac{W \times l}{F + W}$$

$$b = \frac{F \times a}{W} \text{ or } b = \frac{F \times l}{F + W}$$

FULCRUM BETWEEN APPLIED FORCE AND DELIVERED FORCE

FIG. 19—THREE DIFFERENT ARRANGEMENTS OF THE APPLIED AND DELIVERED FORCES

A car weighing 46 700 pounds without load, has a weight of 32 200 pounds on the motor truck and 14 500 pounds on the trailer truck. The motor truck is equipped with inside hung wheel shoes connected directly to a double set of levers, no break beams being

used. The trailer truck has outside hung shoes mounted on brake beams, consequently a single set of levers is used. One hundred per cent. brake power on the motor wheels requires a force of 8 050 pounds at each brake shoe. Ninety per cent. brake power on the trailer truck requires a force of 6 525 pounds at each brake beam. The total brake power will be 45 250 pounds, and as a 10-inch piston under a pressure of 60 pounds per square inch exerts a force of 4 700 pounds, the total leverage ratio will be about 9.6 to 1, which is satisfactory. The levers supplied with the motor truck are 27 inches long and the shoes are hung $7\frac{1}{2}$ inches from the lower end. Considering the dead lever first with its fulcrum at the upper end we know the delivered force W and its distance b from

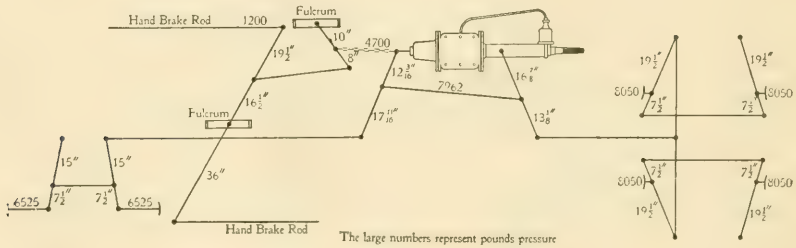


DIAGRAM SHOWING CALCULATIONS FOR A SPECIFIC EXAMPLE

the fulcrum, also the distance a from the fulcrum to the applied force F; substituting these values in the equation $F=\frac{W\times b}{a}$ we have $F=\frac{8\,050\times 19.5}{27}=5\,814$ pounds as the stress in the adjusting rod. Considering the lower end of the live lever as the fulcrum we have $W=8\,050$ pounds, $b=7.5$ inches and $a=27$ inches; consequently the pull at the upper end, $F=\frac{8\,050\times 7.5}{27}=2\,236$. The proof is that $5\,814+2\,236=8\,050$. As a pull of 2 236 pounds must be exerted on each side of the trucks, the stress in the truck pull rod will be 4 472 pounds.

For the dead lever of the trailer truck we have $W=6\,525$ pounds, $b=22.5$ inches and $a=15$ inches, consequently the stress in the adjusting rod is $F=\frac{6\,525\times 22.5}{15}=9\,787.5$ pounds. With the intermediate point of the live lever taken for the fulcrum $W=6\,525$ pounds, $b=7.5$ inches and $a=15$ inches, and the stress in

the pull rod $F=\frac{6\,525 \cdot 7.5}{15}$ 3 262.5 pounds. The proof is that 6 525+3 262.5=9 787.5.

It is now necessary to so proportion the push rod lever that with a piston force of 4 700 pounds it will deliver 3 262 pounds (neglecting the half) to the trailer truck pull rod, and the cylinder lever that it will deliver 4 472 pounds to the motor truck pull rod. For efficient operation of the slack adjuster these levers should not be less than 30 inches long; with short levers the action of the adjuster would cause excessive angular distortion. If the applied force at the cylinder end of the push rod lever is 4 700 pounds, and the delivered force at the pull rod is 3 262 pounds, that at the cylinder will be 4 700+3 262=7 962 pounds. Assuming that the pull rod pin is the fulcrum we have F=4 700, a=30 inches, W=7 962, and $b=\frac{F \times a}{W}=\frac{4\,700 \cdot 30}{7\,962}=17\frac{11}{16}$ inches. For the cylinder lever we have F=7 962 pounds, W=4 472 pounds, and b=30 inches, therefore $a=\frac{4\,472 \times 30}{7\,962}=16\frac{7}{8}$ inches.

With the ordinary brake handle, staff and chain supplied with electric cars, 1 200 pounds is about as much force as the average man can exert on the hand brake pull rod. This must be multiplied to 4 700 to give the same brake power by hand as by air pressure. Using a multiplying lever 18 inches long and connecting to the push rod pin by a chain fastened 10 inches from the fulcrum the force required at the end of the level will be $\frac{10 \times 4\,700}{18}=2\,611$ pounds. Assuming that the hand brake lever is six feet long and pivoted at the center we have F=1 200 pounds, a=36 inches, W=2 611 pounds, and $b=\frac{1\,200 \cdot 36}{2\,611}=16.54$ inches, or practically $16\frac{1}{2}$ inches.

In order to avoid the loss of power by unnecessary friction it is essential that all levers and rods be supported by suitable hangers. In too many cases hangers are carelessly designed, or badly secured. Such construction necessitates the employment of very stiff release springs, so that a large percentage of the brake power is required to merely draw the shoes up to the wheels. Extreme care must also be exercised that there are no obstructions to prevent the full travel of the parts of the leverage system. The maximum power is exerted when the forces are acting perpendicularly to the levers, thus the cylinder rod should be of such

length that, with the piston out of its normal stroke and the slack adjuster half run out, the two levers stand parallel to each other and perpendicular to the cylinder rod. When there is no slack adjuster the cylinder lever should be given half the angularity of the push rod lever.

It now remains to so proportion the various parts of the brake rigging that it shall have sufficient strength to withstand the shocks to which it may be subjected without deflection, and yet not be excessively heavy.

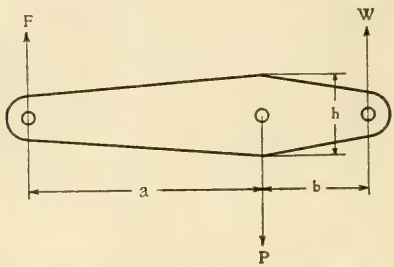


FIG. 20—STANDARD LEVER ARM FOR BRAKE RIGGING

As far as the action of the three forces are concerned, all levers may be considered as beams suspended at the two ends with the load applied at a point between those of suspension as shown in Fig. 20.

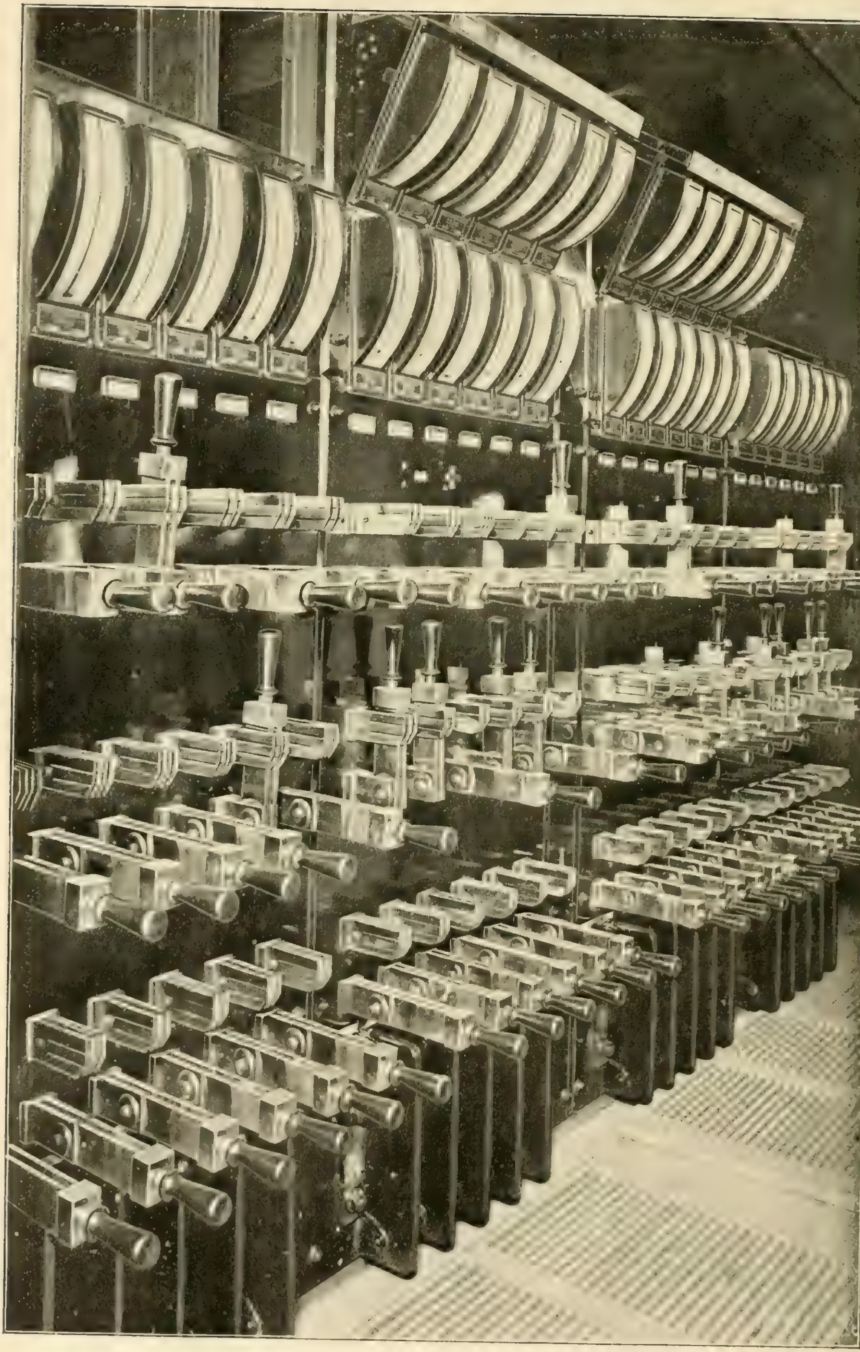
We know the forces F, W and P and the lengths a and b; we must determine the width at the point of application of the greatest force, and the thickness, t. The section of the lever at p must have a resisting moment equal to the moment of the forces applied at the ends of the lever, Fa or Wb, which are equal to each other. Thus $Fa=\frac{f\times I}{\frac{1}{2}h}$ in which the moment of inertia of the section, $I=\frac{t\times h^3}{12}$ and f=the maximum safe strain per square inch. Substituting this value for I in the previous equation gives $Fa=\frac{f\times t\times h^2}{6}$ or $h=\frac{\sqrt{6\,F\times a}}{\sqrt{\;ft}}$ (1). In this formula the effect of the hole has not been considered. Taking the hole into account and assuming that it is located on the neutral axis or central line of the lever, $I=\frac{t\,(h^3-d^3)}{12}$ and $Fa=\frac{f\times t\times(h^3-d^3)}{6h}$ (2).

To determine the effect of leaving the hole out of consideration let us work out an example in which F=3 300 lbs., W=6 600 lbs., a=20 inches and b=10 inches. It is customary to make all levers one inch thick, except when the loads are very light, in which case a thickness of three-quarters of an inch is sufficient. We will assume t=1 inch. Experience has shown that for levers and rods of wrought iron or low-grade steel it is

satisfactory to use the following values of f:—for levers 23 000 pounds per square inch, for rods in tension 15 000 pounds per square inch, and for pins in shearing strain 8 000 pounds per square inch. Substituting these values in formula (1) we have, when leaving the hole out of consideration $h=\frac{\sqrt{6\times 3\,300\times 20}}{\sqrt{23\,000\times 1}}=4.15$, say $4\frac{1}{4}$ inches. The standard diameter for brake pins set by the Master Car Builders' Association is $1\frac{3}{64}$ inches, working in holes $1\frac{1}{8}$ inches in diameter. Thus from formula (2) we have $3\,300\times 20=\frac{23\,000\times 1\,(h^3-1.125^3)}{6h}$ or $h=4.18$. This calls for a lever only .03 inch wider than the much simpler formula (1), and which would still be narrower than the $4\frac{1}{4}$ inches decided upon above, consequently the effect of the hole is negligible. The bending moment reduces as the distance from the point of application of the force diminishes, therefore, at that point the moment becomes zero and there remains only a shearing force. Consequently the lever must be made with ends wide enough to withstand the shearing effect, and taper uniformly from the maximum width to that at the ends. A convenient practice is to make the ends of all cylinder levers $2\frac{1}{2}$ inches wide.

The following table of sizes of push rods and cylinder levers, to be used in conjunction with the table on page 107, may be of use in designing a body rigging. The cylinder rod must be connected at a point lying between the minimum and maximum distances from the push rod pin. If in order to obtain the proper total leverage ratio it is necessary to locate this point further from the push rod pin than the given maximum distance the section of the lever at this point must be enlarged.

Diameter of cylinder in inches.	Length of cylinder levers.	Distance from push rod to cylinder rod. Minimum.	Distance from push rod to cylinder rod. Maximum.	Maximum Section of lever.	Diameter of cylinder rod.
6	26	8	$12\frac{1}{2}$	$3\times\frac{3}{4}$	$\frac{3}{4}$
8	26	8	$12\frac{1}{2}$	3×1	$\frac{3}{4}$
10	28	8	$12\frac{3}{4}$	4×1	$\frac{7}{8}$
12	$31\frac{1}{2}$	9	$14\frac{1}{8}$	5×1	$1\frac{1}{8}$
14	35	10	15	6×1	$1\frac{1}{4}$



A SPECIAL LIGHTING FEEDER SWITCHBOARD, USING THE THREE-BUS SYSTEM, IN M'CLELLAN ALLEY SUB-STATION OF THE UNITED ELECTRIC LIGHT & POWER COMPANY, BALTIMORE. THIS BOARD IS EQUIPPED WITH VERTICAL EDGEWISE TYPE OF VOLTMETERS AND AMMETERS, THREE SELECTOR SWITCHES IN VERTICAL ROWS AND OPEN FUSES FOR EACH FEEDER

MODERN PRACTICE IN SWITCHBOARD DESIGN

PART IV

BY H. W. PECK

IN railway equipment, reliability, simplicity and the ability to give hard service without damage, are the important items in the consideration of the electrical equipment. For lighting service reliability and regulation are the prime factors. The common use of the double-throw system for lighting service has been noted. Common use is also made of three and four sets of bus-bars with selector switches in each generator and feeder circuit so that they may be connected to any of the bus-bars. With only two sets of busses it is usual to obtain the required regulation direct from the generators, using different ones for the two busses, of course If the range in voltage requires more than two sets of busses, boosters are usually required to obtain the higher pressures. With a booster one generator can serve two or more sets of bus-bars if the total power consumed does not exceed its output.

This system provides for generation and distribution at approximately the voltage of consumption which is usually 110 volts, sometimes 220 volts, since successful commercial lamps have been made for that pressure. At this pressure to afford the close regulation required for lighting, and to avoid excessive loss in distribution, requires a very large amount of copper in the distributing lines. By doubling the pressure and connecting the same number of lamps across the line in groups of two in series, the current required will be reduced one-half and the allowable drop in pressure for the same regulation will be double the previous amount; or by connecting two machines in series and the lamps in series, in pairs across the outside lines, the total current will be reduced one-half and the total length of the line will be reduced one-half the amount of the original arrangement. From either consideration we see that a saving of 75 per cent. in copper will result. As the operation of two lamps in series is not satisfactory, a third or neutral wire of one-half or sometimes of the same size as the others is added. This reduces the saving in copper to 69 or 62.5 per cent., but allows of the use of both 220 and 110 volts apparatus on the same circuits. This three-

wire system is obtained in several ways. The most common are called the Edison, the balancer and the three-wire generator systems.

THE EDISON THREE-WIRE SYSTEM

Fig. 11 shows the standard connections for a 110-220 volts Edison three-wire system, two generators, one three-wire feeder, one 220-volt feeder and two 110-volt feeders being shown. The two generators are connected in series. The two outside terminals are connected to the positive and the negative bus-bars, the middle terminals are connected together at the neutral bus. The equipment of apparatus for the control of each generator is standard except that with two machines no equalizer is necessary. With an installation of two or more pairs of machines, two equalizer connections are required, one between the machines connected to the negative bus and one between those con-

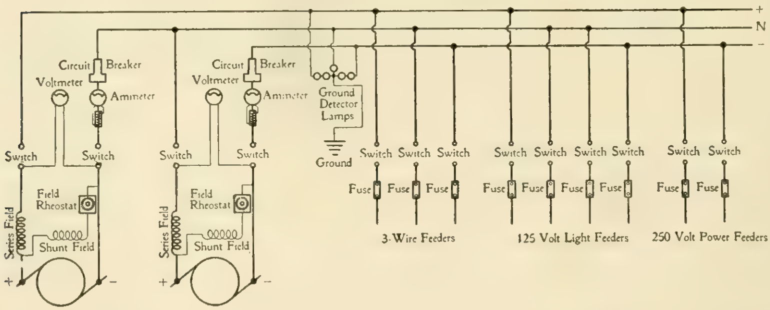
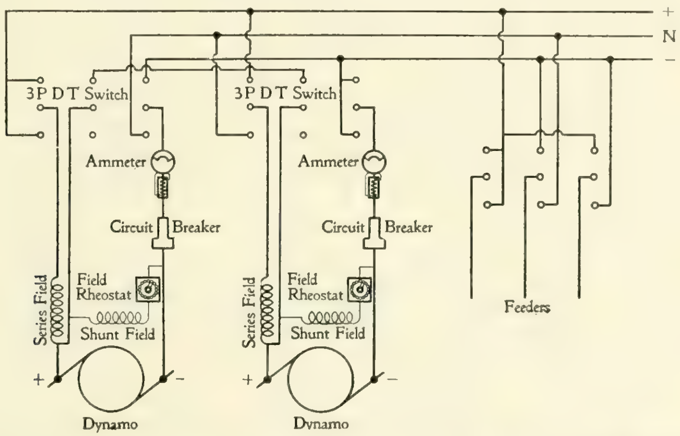


FIG. 11—DIAGRAM OF STANDARD CONNECTIONS FOR EDISON THREE-WIRE SYSTEM

nected to the positive bus. The operation of this system is practically the same as that of a single voltage system. The voltages of the generators are brought to the same proper value without load. The series coils automatically regulate the voltage as the load changes. The neutral wire is positive or negative with respect to the true neutral as the load is greater on the negative or positive side respectively. The feeder circuits are usually equipped with three-pole switches, but power circuits and some short, low capacity lighting circuits may require only two-pole switches. Protection is generally afforded by enclosed fuses, but circuit breakers may be used if warranted. Ground detector lamps are provided in the usual way, two between the positive and the negative busses and the ground. Standard panels, as previously shown and described are used for this equipment. It is some-

times desirable to operate a small system either as a two-wire or a three-wire system. The occasion for this will arise either when the load becomes so light as to be within the capacity of one machine and allowable line loss, or when an isolated system of one kind wishes to receive power from a general city system of the other kind. Fig. 12 shows the connection to enable this change to be effected. Each generator and feeder is provided with a double-throw switch instead of a single-throw switch.



. FIG. 12—DIAGRAM OF CONNECTIONS FOR OPERATING A SMALL SYSTEM EITHER TWO-WIRE OR THREE-WIRE

The two-wire system will of course supply power at the lower voltage only so that apparatus connected across the outer wires can not be used.

THE BALANCER SYSTEM

For a system which requires more power than can well be supplied by two generators connected for the Edison system, standard generators of normal voltage equal to the pressure between positive and negative bus-bars and a balancer set to automatically take care of the unbalanced load are installed. Fig. 13 shows the connections for such an installation. The equipment for each main generator is standard except that the circuit breakers are provided with an auxiliary tripping coil in addition to their usual automatic overload device. The balancer set comprises two machines mechanically connected to each other, but not connected to a prime mover. Each machine is designed for half of the voltage of the main generators and has a com-

pound wound field. They are connected in series across the positive and negative bus-bars and are controlled and protected by single-pole switches and fuses in each lead.

In the positive or negative lead is also connected a starting and stopping rheostat with minimum release. The shunt fields of the machines are connected in series across the positive and negative leads outside of the starting rheostat, and the connection between the two is connected to the neutral lead through a switch. The functions of this set are best understood by considering the operation of the installation from the start through different conditions.

All switches being open, one of the main generators is first started, brought up to normal speed and voltage, and thrown on the bus-bars. The positive and negative switches of the balancer set are closed and by means of the starting rheostat the two

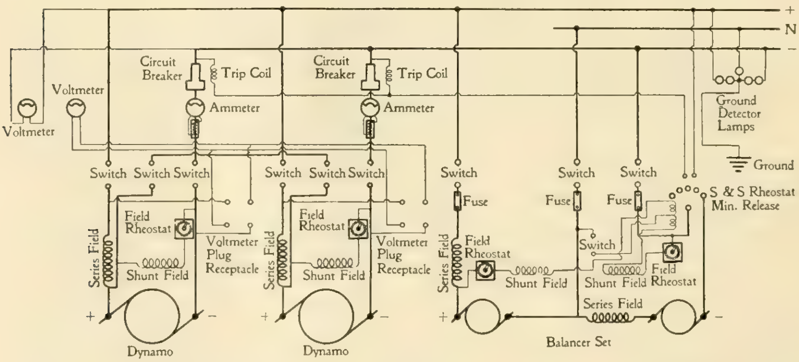


FIG. 13—DIAGRAM OF STANDARD CONNECTIONS FOR TWO, TWO-WIRE DYNAMOS USED WITH A BALANCER SET TO SUPPLY A THREE-WIRE SYSTEM

are started together as motors running light. The starting rheostat is designed with eight or ten contacts, through which the contact arm cuts out the resistance in successive steps and finally short-circuits all of it. The arm is held in this position against the effort of a spring, by a magnet coil. This coil is made in two parts which are connected in series with the shunt field windings of the two machines. If the voltage of the circuit falls below 50 per cent. of normal or the current through either field be interrupted the magnet will no longer hold the arm and it will fly back to the open position, disconnecting the motor from the circuit. When in the open position the arm closes the circuit between the two auxiliary contacts shown just above the main

contacts. When the rheostat has been all cut out the neutral and the field switches are closed. It is necessary to disconnect the middle point of the fields from the neutral in starting or the armature of the machine further from the starting rheostat will short-circuit its field winding and double voltage will be applied to the other field winding. When the machines are running the field coils must be connected to the neutral to obtain satisfactory regulation. This explains the use of the field switch. The feeder switches are next closed and the plant is in operating condition until the increase in load makes it necessary to parallel another main generator with the first, which operation is performed in the usual manner.

If there is an excess load on the positive side of the system the pressure between positive and neutral will be less than between neutral and negative. The negative balancer will tend to speed up and will drive the other as a generator. The unbalanced current will divide, part going through the motor balancer to afford the power to send the rest through the generator balancer back to the line. The series winding of the former tends to weaken the field and increase the speed, that of the latter assists the shunt winding and raises the voltage across the generator. If the excess load be on the negative side, the positive balancer becomes the motor, the negative balancer the generator. It is evident that these machines do not add any power to the system, but serve only to balance the load on the two sides. On the other hand, they consume only such power as is represented in their losses, which is small compared to the total power of the station and to the power which would be lost in distribution were a two-wire system used. Each balancer should have a capacity equal to one-half the maximum unbalanced load that is considered probable to occur. For, as mentioned above, the unbalanced current divides approximately equally between the two machines, the motor taking just enough additional current to make up for the losses in the two machines.

If the circuit-breakers of the main generators open so that the bus-bars become dead, the starting rheostat of the balancer set is automatically cut in. This avoids the danger of closing the main circuits when the balancer set is idle but connected across the circuit. It is necessary to have the balancer always running when the system is alive, as otherwise the lamps on the side with the lesser load will be burned out. To insure against

this condition obtaining if the balancer set be cut out, tripping coils are placed on all of the main circuit breakers connected in parallel with each other in series with the auxiliary contact on the starting rheostat. When the arm of the rheostat opens the balancer circuit, it closes the circuit across the auxiliary contacts and trips the main circuit breakers Before starting again all switches must be opened as in first starting up the plant. There is placed in the circuit between the contacts and the tripping coils a plug switch which is opened when the first generator is started and closed after the balancer set is running.

THREE-WIRE GENERATOR SYSTEM

A three-wire generator can be installed alone or to operate in parallel with two-wire machines or other three-wire machines. The general characteristics have been already described. Fig. 14

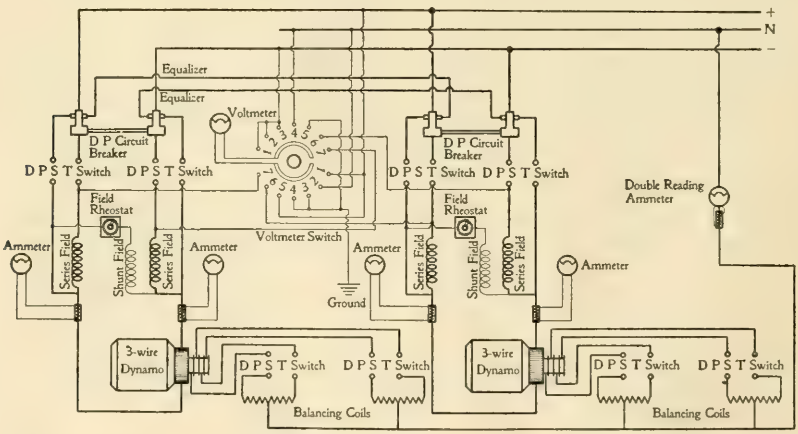


FIG. 14—DIAGRAM OF STANDARD CONNECTIONS FOR TWO THREE-WIRE GENERATORS

shows the connections for operating two of these dynamos in parallel. Half of the series coils are in the positive lead, half in the negative, in order that any unbalanced load may have its due share in the regulation of the machine. As there is no single lead through which all the power must pass as there is in a two-wire generator, each of two loads must have an ammeter and a circuit breaker. As each of these leads divides in two parts, main and equalizer, at the terminal block of the machine, it is necessary to connect these instruments in the circuit between the brush holder and the terminal block or else to provoide special apparatus.

The best practice is to mount the ammeter shunts at the machine in the brush holder leads and to provide circuit breakers with an extra contact for the equalizer connection. This contact does not have to carry or break as much current as the main contact and there is but little pressure to break or difference in pressure between main and equalizer contacts to require insulation, so that the addition is a simple matter. With this arrangement both the ammeters and the circuit breakers are located on the switchboard where they are convenient for operation The two circuit breakers are made as double-pole breakers, so that an overload on one side will open both sides of the circuit. It is usual to connect a double reading ammeter in the neutral bus to read the direction and the amount of the net unbalanced load. In this diagram is shown a seven circuit voltmeter switch which is convenient but not more necessary to a three-wire generator installation than to any other three-wire system.

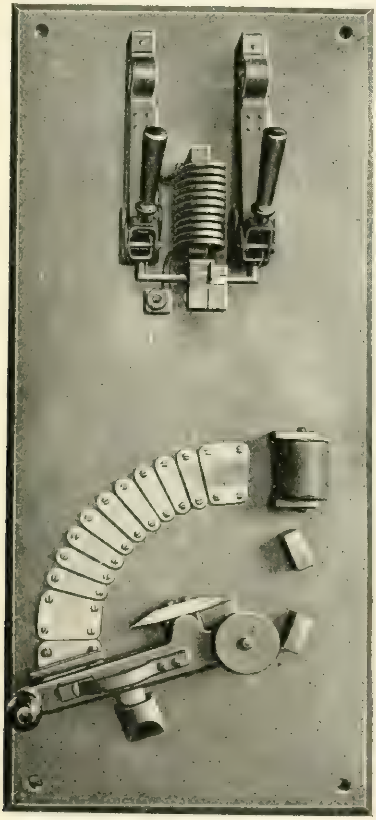


FIG. 15—STANDARD DIRECT-CURRENT MOTOR PANEL

The requirements of a motor circuit are few, the chief ones being that the apparatus used must be strong and simple in operattion. The advantage of mounting this apparatus properly on a panel is being appreciated and standard panels are designed for all sizes of motors up to 50-hp, 110 volts, and 100-hp, 220 volts, suitable for mounting on a machine tool on small brackets, or on standard switchboard frame. Fig. 15 shows such a panel. The equipment comprises an automatic double-pole, type D circuit breaker, a starting rheostat and a field rheostat. The poles of the circuit breaker are arranged to close independently but to open together on overload. The pole that is first closed will

open when the second pole is closed if there is a short circuit or other overload on the line. This supersedes the switch and fuses commonly used. The starting rheostat is arranged for minimum release and is similar to the one described in connection with the balancer set except that the auxiliary contact is omitted. The holding magnet and the short circuiting contacts are clearly shown in the illustration. A field rheostat is required only with variable speed motors.

The control equipment for storage batteries varies very much with the method used for charging, the use which is made of the battery, etc. Most storage battery manufacturers have patented appliances which they use in the control of their batteries and which are described in their circulars. These are all of a special nature and it is not deemed within the scope of these articles to describe storage battery switchboards.

SOME DIFFICULTIES IN GETTING ON*

By JAMES SWINBURNE

NONE of the Eastern sages give advice that is specially applicable to the electrical engineer wishing to rise in his profession, so I think I may try to say something useful. I therefore propose to talk to you about a few of the difficulties in getting on.

The first difficulty is to know what equipment is necessary and how to get it. That is to say, to know what ought to have been learned and how to make up any deficiencies. At once each of us is confronted with the question, "What is going to be my work?" I say "us" because the difficulty in many cases is permanent; one never knows what he will be called upon to tackle in the future. The difficulty is much greater, however, in the case of a young man, because he has probably the vaguest idea of what his life's work will be, and that idea time will show to be quite wrong.

In engineering it is quite impossible for anyone to start out with a definite career before him. He is like a particular particle setting out across a containing vessel of gas. He cannot careen straight across. He is buffeted about and frequently goes in

*Abstract of an address delivered to the students of the British Institution of Electrical Engineers, November 16, 1904.

quite the wrong direction. If he is charged and in a field, he will zigzag across in front of most of his fellows. A man who has made a specialty of electric waves, gets his first appointment as inspector of meters for an electric light company, and so on. A well known engineer remarked to me the other day, that he found his knowledge of differential equations, and his experience in the correct analysis of the rare earths, was of little use in putting in sewage plants; yet he had made lots of use both of his mathematical and chemical analysis in his time. Probably each man should have a general knowledge of applied physics and chemistry and mathematics, and a special knowledge of one or two subjects. The special knowledge may never come in useful; but the chances are that in the blind stumblings we call our careers, a specialty may be very valuable. If you glance round at the work of some of our big men you will be surprised to see how many have made their reputation by doing one small thing, but doing it well. If a man gets to the front in one narrow subject the world credits him with knowledge of all the rest. It is, however, even easier to acquire a large general knowledge than an advanced special knowledge of one narrow subject. The specialty must not be too narrow either.

One of the great difficulties is to keep knowledge in a polished state ready for immediate use. In practice it may have to lie idle for long periods and then be wanted very much on short notice. This fact is overlooked by people who suffer from the modern craze for writing about technical education. For instance, we are told that all engineers ought to have the calculus at their finger ends, and so on; but it is forgotten that though an engineer ought to be well up in mathematics, he only makes a calculation requiring higher mathematics once in several years, perhaps; and it is impossible for him to keep his mathematics in working order down to minute details. All he can do is to keep general principles in his mind. Probably the only thing to do is to treat knowledge as a huge district into which one's life is long enough to make some very little roads. From each main road there are branch roads, from each branch road little paths, and so on to an infinite extent. Many places can be reached by several paths. Each road or path gets obliterated by weeds if it is not constantly trodden. Life is too short to make many roads or paths, and very much too short to keep many of them in order by constant use. The best thing then is to keep one or

two main roads clear, and remember where the branch roads and paths are, and go over them again when needed. To go back to plain speaking, the great thing is to master a certain number of broad fundamental principles which will give a starting point for refreshing old knowledge or acquiring new.

As to how a man ought to be technically educated; that is not a matter for me to discuss. It is a very large subject. I would only refer to one aspect of it. One of the greatest difficulties in getting on arises from the idea, which is carefully fostered among English science teachers, that there is something degrading in applying science, and that business ability is an inferior quality and is to be despised.

If you imagine a school or college, which somehow came into existence and gave a good education, teaching the things that are useful in a useful way, and imagine that after a time new masters have been chosen out of the old pupils, who will get the appointments? The old pupils will consist of clever men who absorbed the education in a practical way, and equally clever men who absorbed the information but gave it a less practical turn. It will also consist of less able men of each kind. The ablest practical men will have gone out into the world, doing its work, and so will many of the less able practically minded men. The able men with a slightly unpractical bent will thus become candidates for the new posts. The next generation of teachers is thus less practical, and the education becomes more and more unpractical as time goes on. There is thus an unavoidable tendency for education to become more and more unpractical.

In science and technical training the same unavoidable evolution toward the unpractical is always going on. It is but human to glorify one's own office. The result is that the attitude of the science teacher in this country is that of real though unavowed antagonism to the scientific development of the industry of the nation. Science, for which no use has been found, or which is not applied, is called pure science, whereas it is really the raw material and should be called raw or crude science. There is an assumption of superiority in the term pure science, and generally the term science is appropriated by workers in raw science in much the same way as the term working man is appropriated to the exclusion of brain workers. There is supposed to be something noble and superior about raw science, and its study is treated as the unselfish devotion to the interests of man,

which is obviously entirely the wrong way round. The so-called scientific man thinks that engineers and manufacturers are ignorant and unscientific, and that their practical knowledge is of no account; and that the cure for all industrial evils is more technical education, more universities and more power to the science masters. Perhaps no one would be more surprised than the average science master if you told him he was unpractical, and was, by his attitude and example, hindering science.

It is often said that the pursuit of knowledge has a nobility of its own. But what knowledge? What is the use of knowledge? Your question at once commands the answer. No knowledge is worth obtaining for its own or any other sake, unless it is or will probably be useful to man.

I would earnestly urge any of my hearers who has the idea that there is something noble and superior about new raw science, or who thinks little of business men, to get rid of all such notions if he hopes ever to get on. If you look round the electrical industry, or round the industries generally, who are at the top? Always the business men. Yet the science teacher looks down with contempt on the engineer as an ignorant rule-of-thumb inferior person, and the engineer in his turn looks down on the business man as a money-grubbing person with no brains and with no lofty ideals. But this is all topsy-turvy. The business man at the top, the practical engineer in the middle and the unpractical engineer, or the raw scientist at the bottom. The business man may have no knowledge of the ways of nature, but he has a knowledge of the ways of man, a knowledge which is infinitely more difficult to employ well. His brain may be different from that of the scientific man; but there is no reason to suppose that it is less. Its convolutions may be different, but the probability is that they are even more complex than those of the scientific man.

A man's value to the world at large may generally be roughly estimated by the income he earns. Where position is earned at the same time, the money income is in proportion less for a given usefulness; but taking such disturbing elements into account, the rule is broadly true.

If you examine the large industries you will, as I say, find the commercial or business man with little or no technical knowledge at the top of the tree. If you confine your attention to engineers, you find the engineers who make the biggest incomes and who occupy the most important and responsible positions

are those who have the most business or practical knowledge. Our leading consulting engineers do not spend a large portion of their lives plotting curves, counting electrons or even making anything more than arithmetical calculations. They spend their time dealing with large questions on purely commercial lines; and as a rule the bigger the engineer the more he knows about practice and business and the less he knows about text book science. I do not for a moment mean to say that text book science is not of priceless value; of course it is; and the more scientific knowledge you or I, or still more, the leading engineers have, the better; but most of us suffer from too little common-sense in proportion to our scientific knowledge.

There is a wide distinction between the man who can earn a few hundreds a year and the man who earns as many thousands. The engineer who is worth £750 a year seems hardly to exist, except for a short time on his way from one class to another. This is what is meant by the saying that there is plenty of room at the top of the ladder. It is not that men who remain as assistants permanently are ignorant of science—quite the reverse. The business man may rent a profound mathematician for a very few pounds a week if he wants him, but he probably does not. The real point is that the assistant is wanting in business knowledge or push. If he is wanting in ambition, or lazy, nothing I can say is to the point; but he may be suffering from a false notion of the relative value of raw science, technology and business knowledge.

When I say that a man's earnings are a rough test of his value of the world, a great exception must be made in the case of genius. A genius does not work for a given employer; he works for the world at large, and the world at large does not pay him. It would be ludicrous nonsense to say that the value of Newton or Faraday could be reckoned in terms of their pecuniary earnings. They did grand work apparently because they were impelled to do it without any selfish motive. This is true of the great scientific men of to-day.

In the charter of the Institution of Civil Engineers the engineer is defined as "directing the great sources of power in nature for the use and convenience of man." With all respect to this august body, and their often quoted definition, I would humbly suggest that it is bad. It is really the definition of a scientific man. It is incomplete as applied to an engineer, because it

does not take into account the sordid element of price. An American definition is much better: "An engineer is a man who can do for one dollar what any fool can do for two." This is not poetical, and is useless for oratorical purposes; but it is right. It is no use being able to design most complicated alternating-current machinery, or being able to explain it with the help of a wilderness of clock faces and several issues of the technical journals, unless the machine, when made, is cheaper than its rivals. Every design, every engineering manufacture and every piece of engineering is only a question of price.

I can not tell you how to be engineers, because I do not know. All I can do is to make you realize some of your wants; and if you know what you want, you are more likely to get it. One of the greatest difficulties in getting on is to find a good opening.

Then as to the different branches of business—business is really a higher title than profession—in which are you to find openings? From the number of applications I receive from young fellows, it seems to be a common idea that consulting engineering is a good thing to begin upon. It is a curious notion. A consulting engineer is supposed to be a skilled engineer, with so much experience that he is an authority. I should have thought at least 20 or 30 years' experience, apart from school and college training, was necessary for a consulting engineer to be worth his salt. But there are various grades of consulting engineers; and I am entirely at a loss to know what the qualifications of the consulting electrical engineer really are.

In manufacturing work there is the designing of dynamos, motors, transformers and so on. This was considered high grade work when I was a young man; and even very able men built some very queer machines in those days; and we were all pretty ignorant. But the works were smaller then, and salaries for dynamo designing were not princely. But now there is not much opening in electrical machine designing. There is some, of course, but it is not as it used to be. There are many openings to be had in central station work; and stations are growing bigger and more important every day. At present there are also many applicants for every opening. Central station work in a position of responsibility is very anxious. I do not think that it is very well paid either. You will find exceedingly able engineers in most of the large town stations; and I am sorry to say their incomes are often very small for men of their technical and

commercial ability. The assistants are often poorly paid, especially I think in municipal stations; although I do not know why this should be.

A large number of young men go in for installation work—which sounds as if they started bishops on their episcopal careers—but really means that they do what is in fact electrical plumbing, under an unnecessarily imposing name. There are a great many of them, and they seem to spend most of their time going into and out of partnership with one another, like lions, and sending notices around to that effect. At other times they go bankrupt and send no notices. The upper grades in teaching science are well paid, more especially as a position goes with an appointment, and there is time and facility for original research, which is a luxury and brings reputation. Moreover, a steady income with no expenses is a very blessed thing. But the lower grades are very poorly paid in proportion to their ability.

All this may sound rather discouraging, but I am dealing with the difficulties of getting on, and I am sure it will not discourage anyone who is worth his salt. At first it is very discouraging to make very little, and the good man has little chance of showing his superiority to the common run. But he should always remember that income as a young man is very little criterion of real value.

I have only mentioned a few of the difficulties in getting on. I am sorry to say there are many more, which you will find out in good time.

The Engineering Magazine (London) publishes the following comment on Mr. Swinburne's address:

"That the engineer cannot be a successful business man is by no means the idea everywhere. In effect it is generally recognized in the United States that a scientific training is an excellent qualification for a business career. The positions of the heads of great railways, manufacturing companies and industrial enterprises, are in many instances filled by men who have risen from engineering positions and who are applying the methods of engineering science to commercial problems. In England the productive engineer has not yet attained the prominence which exists in America, but he is not altogether unknown, and there is ample room for him and his work in a field as yet all too little cultivated."

FACTORY TESTING OF ELECTRICAL MACHINERY—XIV

By R. E. WORKMAN

ROTARY CONVERTERS

A ROTARY converter is a machine for converting alternating current to direct current, or vice versa. In construction it is very similar to a direct-current generator, having the same type of armature and commutator and a similar field. In addition to these parts, however, there are slip rings on the rear of the armature tapping the armature winding at certain places, so that the sections of the winding, considered in connection with the slip rings, correspond to the armature winding of a ring or delta-wound alternator.

Rotary converters may be divided into two classes: (a) those for conversion from alternating-current to direct-current, here called simply rotary converters, and (b) those for conversion from direct-current to alternating-current, called inverted rotary converters. The same machine may be operated either way, as there is no essential difference in construction.

(a) ALTERNATING-CURRENT TO DIRECT-CURRENT TYPE

These may be considered simply as synchronous motors with the addition of a commutator at the other end of the armature. When running at no load this analogy holds perfectly, but, when load is applied, the conditions are altered considerably and require special notice.

Consider any armature conductor of either a direct or an alternating-current machine revolving in a given direction. If the machine is running as a generator, the current in the bar will be in one diretction, while, if the machine is running as a motor, the current will be in the reverse direction. In the armature conductors of a rotary converter which is running as a synchronous motor, and is loaded as a direct-current generator, the current in any given conductor at any instant will be the difference between that which would be flowing if the converter were a synchronous motor on a mechanical load of such magnitude as to give the same imput, and that which would be flowing if the converter were mechanically driven and loaded on its direct-current side to give the same output. Since rotary converters are usually operated with high-power factors, these currents will oppose each other, and the resultant armature current will general-

ly be quite small. This is more especially true of polyphase converters where the action is distributed over the armature. In single-phase converters the resultant current is large. The small ness of this resultant current manifests itself in the consequent smallness of the armature reaction and of the resultant heating.

The relative power ratings for the same heating due to armature copper loss in the same machine under different phase running are as follows:

As Continuous Current Gen.	As 2-Ring Converter.	As 3-Ring Converter.	As 4-Ring Converter.	As 6-Ring Converter.
1	0.85	1.33	1.625	1.93

These different outputs being accompanied by the same heating due to armature copper loss are evidently accompanied by different resultant or equivalent currents in the armature winding. The actual current flowing in the armature is not equal in all of the conductors. The currents in those conductors which are adjacent to the connections leading to the rings are greater than the currents in the conductors which are more remote. The heating is therefore not equally distributed among the different conductors.

The relative power ratings for the same heating which are above given are based upon an efficiency and power-factor of 100 per cent. For other power-factors the heating in the armature conductors is increased and the power ratings for the same heating are consequently reduced. On the other hand, if the output of a rotary converter be held constant, the heating will increase as the power-factor diminishes.

This means that for a constant current output at the direct-current brushes, the resultant current in the winding, for different phase running, will be the reciprocals of these quantities, as follows:

As Continuous Current Gen.	As 2-Ring Converter.	As 3-Ring Converter.	As 4-Ring Converter.	As 6-Ring Converter.
1	1.18	0.75	0.62	0.52

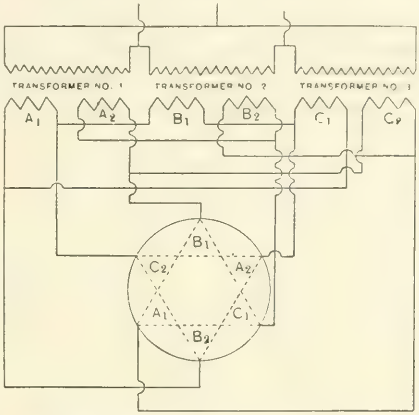
THE E. M. F. AND CURRENT RELATIONS IN ROTARY CONVERTERS

In calculating these relations it is convenient to take the case of a two-pole converter and to assume that the e.m.f. induced in any conductor on the armature periphery is proportion-

al to the sine of the angle between the radius which passes through it and a line at right angles to the axis of the poles. This is very nearly the case in a well-designed converter. An efficiency of 100 per cent. and a power factor of unity are assumed in calculating the current ratios. Of course the results derived are applicable to machines of any number of poles.

The majority of converters now in operation are two or three-phase. A few are six-phase, in which instance there are two practicable arrangements of the transformers:

(I) With three transformers across the three diameters.



SIX-PHASE ROTARY CONVERTER OPERATED FROM THREE TRANSFORMERS ARRANGED IN DOUBLE DELTA

(II) With three transformers having their secondary windings in two halves, each half across two sections of the winding. This is called double delta.

RATIO	2-Ring	3-Ring	4-Ring	6-Ring (I)	6-Ring (II)
Terminal E. M. F., A. C. Side / Terminal E. M. F., D. C. Side	0.707	0.612	0.707	0.707	0.612
Alternating Current in lines . / Direct Current in lines . . .	1.414	0.544	0.707	0.236	0.272

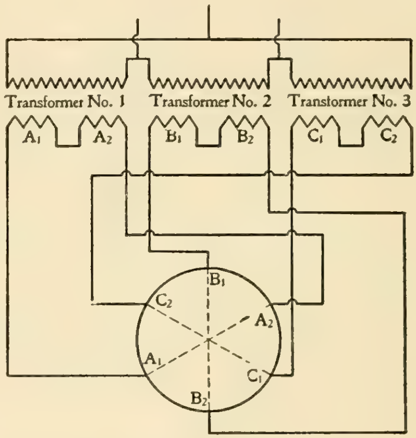
It will be seen that the same design of converter will suit all three cases, the difference being in the transformer connections.

(b) ROTARY CONVERTERS, DIRECT-CURRENT TO ALTERNATING-CURRENT

These machines may be considered as direct-current motors with taps at one end of the armature to slip rings. When running with no load on the alternating-current side, there is no difference between their action and that of an ordinary direct-current motor. As soon, however, as the circuits on the

alternating-current side are completed, the conditions are altered. With the same reasoning as that for the case of an alternating-current to direct-current rotary converter it will be found that the resultant armature current at any instant has a similar relation to the direct-current input and to the alternating-current output. The relative power ratings for the same machine running under different phase conditions will be the same as in the case of alternating-current to direct-current converters.

In the case of direct-current to alternating-current converters, the speed is not constant for all field currents, but increases greatly when a lagging current is taken from the converter, owing to the weakening of the field by armature reaction. It is therefore necessary to separately excite all such converters by means of a small, direct-current generator coupled or bolted to the shaft of the converter or driven by an induction motor actuated by current from the alternating-current side.



SIX-PHASE ROTARY CONVERTER OPERATED FROM THREE TRANSFORMERS ACROSS THREE DIAMETERS

EXPERIMENTAL TESTS

In general the tests made on rotary converters are the same as those made on synchronous motors. The same tests are made whether the machine is to operate as a direct or an inverted rotary converter.

(1) Resistance measurement.
(2) Iron-loss and friction. Saturation.
(3) Short-circuit.
(4) Synchronizing with starting motor.
(5) Input-output efficiency.
(6) Temperature.

(1) RESISTANCES.—These are measured on the direct-current side in exactly the same way as in the case of a direct-current generator. It is usually quite sufficient to measure the resistances on the direct-current side, since, from these the resistances

on the alternating-current side can easily be calculated if the type of winding is known. From the results of the resistance measurement on the direct-current side, the uniformity of the winding is at once apparent.

(2) Iron-Loss and Friction, Check on Armature Windings, Saturation.—The iron-loss and friction test is made in two

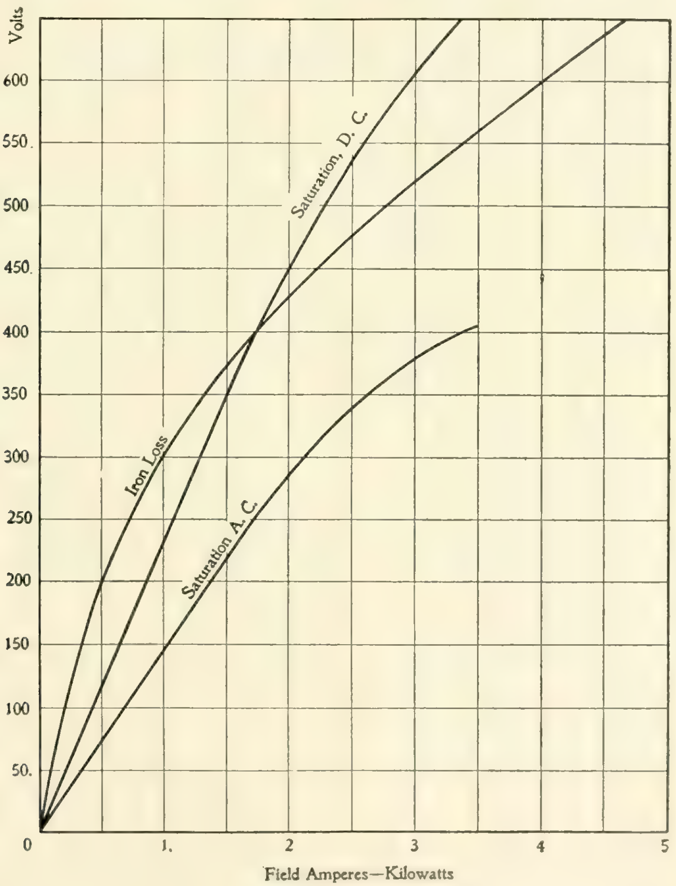


FIG. 68—IRON LOSS AND SATURATION CURVES OF A 2,250-KW., THREE PHASE, 500-VOLT, 25-CYCLE, ROTARY CONVERTER

different ways: (a) With a driving motor as in testing any other direct-current or alternating-current machine. (b) Running the converter as a shunt motor.

The first method (a) is employed when it is convenient to belt the converter to a driving motor. In the case of converters

which are started by means of an induction motor on the shaft, the primary and frame are removed from the induction motor and the belt stretched over the secondary of the induction motor as a pulley. In the case of converters which have no starting motor, unless, as is often the case, a keyway is provided, it is necessary to shrink a tight-fitting half coupling on the end of the shaft To this coupling is fixed an extension shaft having a pulley keyed to it.

The iron-loss readings are taken exactly as explained before and plotted to the direct-current voltage. An iron-loss curve, found in this way for 2 250-kw., three-phase, 500-volt (direct-current) 25-cycle converter, is shown in Fig. 68.

(b) IRON-LOSS AND FRICTION RUN AS A SHUNT MOTOR.—This test is made in cases where it is difficult to belt the converter to a driving motor. The machine is run with a number of different terminal voltages, but the same speed; the speed being held constant by altering the field current. It is thus possible to plot a curve between the armature input in watts and the terminal e.m.f. As the armature input is the sum of iron and friction losses, for a given field current, this curve will give the relation of iron-loss plus friction to the terminal e.m.f., the speed being held constant and the terminal e.m.f. being the independent variable. This curve is plotted down to a comparatively small field current and from this point continued by eye to the point of zero voltage. The watts input from this point will be simply that required to overcome the friction of the machine, which may be assumed constant for a given speed. A straight line through this point parallel to the vertical axis will represent the friction-losses for this speed. From these two curves by simple subtraction, the iron-loss for any voltage may be determined.

Preparations for Test.—The converter is connected through an iron-loss table. The series coils are either cut out or short-circuited.

Conduct of Test.—The machine is started up in the ordinary manner, from the table. The brushes are set as nearly as possible on the no-load neutral, which may be found very approximately in the usual way. The test may then be made as described above. Throughout the test, the readings are to be taken at the rated speed of the machine. The first reading taken will be one at a voltage higher than the working voltage of the machine. Other readings are taken over a range of lower voltages.

Working up Results.—Fig. 69 shows the iron-loss and fric-

tion curve for the above machine found by this method plotted to direct-current volts.

This method is, at best, a rough one, and is seldom used except in the case of duplicate machines.

Saturation.—This is plotted from the readings of either of the last two tests, simply correcting them for inaccuracies in the instruments. The results from the test running the converter as a shunt motor are subject to inaccuracies from the ohmic drop

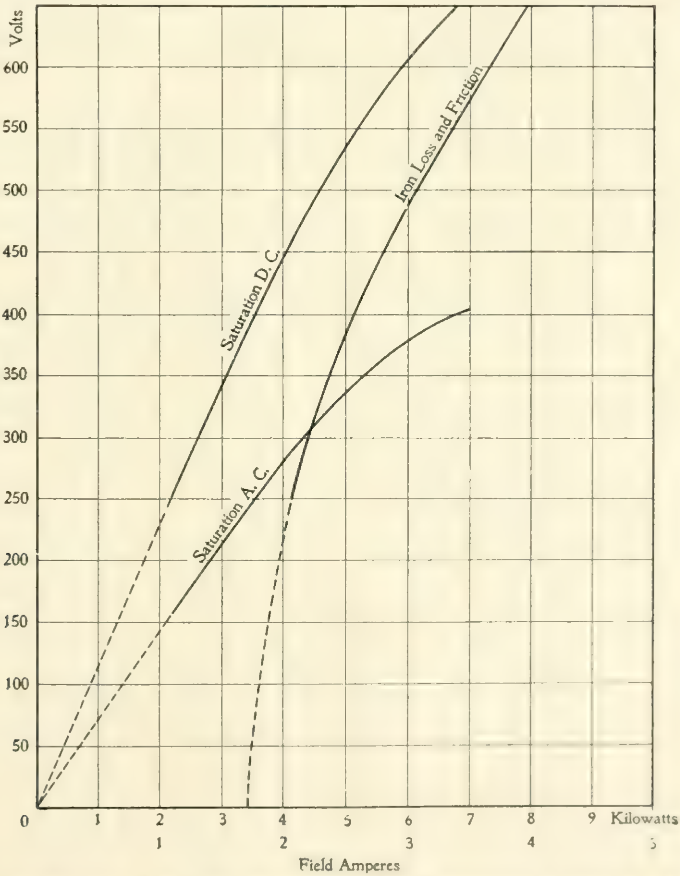


FIG. 69—IRON-LOSS AND FRICTION CURVE AND SATURATION CURVES TAKEN BY RUNNING THE ROTARY CONVERTER AS A SHUNT MOTOR

in the armature windings, which varies directly as the armature current. Corrections may of course be made for this, as the armature resistance is known. The saturation is plotted both for the alternating and direct-current sides of the machine.

FEEDER AND RAIL DROP

By J. W. WELSH

DIRECT-CURRENT RAILWAY PRACTICE

THE following method will be found convenient for the calculation of simple lay-outs where the number of circuits are few. Obviously it is not adapted for the case of city service where the problem is complicated by a network of conductors and a multiplicity of paths.

To determine the feeder and rail drop in any given case it is necessary to know the maximum number of amperers required, the distance of the load from the source of supply and the number and size of conductors. With this information, which is usually readily obtainable, the drop in voltage can be calculated by means of the accompanying table.

A simple example will illustrate the method in the case where several feeders supply direct current to an interurban electric road.

Consider a straight, level line 20 miles in length with the power house situated at the middle. With a schedule speed of 20 miles per hour and a car leaving each terminal every half hour there will be four cars on the line at a time. Assuming that 100 amperes are required to accelerate one car on the level, the maximum current required at each end of the line will be 100 amperes, since there is but one car there at a time.

Considering each half of the line separately the load is 100 amperes at a distance of 10 miles. With a feeder of 532 000 circular mils in parallel with a 000 B. & S. trolley wire (168 000 circular mils) the total cross-section of copper will be 700 000 circular mils. Referring to the table opposite 700 000 and under 10 mile column we find 78 volts, which is the drop per 100 amperes at the end of the line. The greatest distance from the power house at which there may be two cars is half way between it and the terminal of the line. There may, therefore, be a maximum load of 200 amperes at 5 miles distance, but although this is twice the load, the distance is one-half, and the drop remains the same.

The rail drop is found in a similar manner from the table.

The values given in the table are for a single track (two

rails) where the resistance of the bonding is taken equal to that of the rails, *i. e.*, as if the rails were continuous. The resistance of the rails is based on a specific resistance of iron equal to nine times that of copper. This is an average value. On the lines of the Manhattan Railway Company of New York City the resist-

SIZE OF CONDUCTOR	VOLTS DROP PER 100 AMP. MILES														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B. & S. 0	52	104													
00	42	84													
000	33	66													
0000	26	52	78												
Circular Mills 300 000	18	37	55	73	92										
400 000	14	27	41	55	69	82	96								
500 000	11	22	33	44	55	66	77	88							
600 000	9	18	27	37	46	55	64	73	82	91					
700 000	8	16	24	31	39	47	55	63	70	78	86	94			
800 000	7	14	20	27	34	41	48	55	62	69	75	82	89		
900 000	6	12	18	24	30	37	43	49	55	61	67	73	79	85	91
1000 000	6	11	16	22	27	33	38	44	49	55	60	66	71	77	82
1140 000 40 Lb. Rails	5	10	14	19	24	29	34	38	43	48	53	58	63	67	72
1300 000 45 Lb. Rails	4	8	13	17	21	25	30	34	38	42	46	51	55	59	63
1400 000 50 Lb. Rails	4	8	12	16	20	24	27	31	35	39	43	47	51	55	59
1600 000 56 Lb. Rails	3	7	10	14	17	21	24	27	31	34	38	41	45	48	51
1700 000 60 Lb. Rails	3	6	10	13	16	19	23	26	29	32	35	39	42	45	48
2000 000 70 Lb. Rails	3	5	8	11	14	16	19	22	25	27	30	33	36	38	41
2300 000 80 Lb. Rails	2	5	7	10	12	14	17	19	21	24	26	29	31	33	36
2600 000 90 Lb. Rails	2	4	6	8	11	13	15	17	19	21	23	25	27	30	32
2900 000 100 Lb. Rails	2	4	6	8	9	11	13	15	17	19	21	23	25	26	28

ance of the third rail is 7.8 times that of pure copper, while the resistance of the track rails is 11.8 that of copper.

Referring to the table under the 10 mile column, with 60-lb. rails the drop is 32 volts per 100 amperes. This must be added to the trolley and feeder drop, giving a total of 110 volts. If the voltage at the power house is 550 the drop is but 20 per cent. This is the maximum drop. The drop at any intermediate point will, of course, be less, its value depending on whether the car is running free or accelerating.

The average drop when the car is running is, of course, very much less, though it varies greatly with the grade of the track.

If instead of running the feeder to the end of the line, it is cut off at the 9-mile point, a saving of copper is effected at the expense of greater drop in the last mile of line. For this case the feeder and trolley drop for nine miles is 70 volts; for one mile of trolley 33 volts, and for ten miles of track 32 volts, giving a total of 135 volts at the end of the line.

It is sometimes found necessary to run a special feeder to a point where, for topographical reasons, an excessive current is required to propel the cars. For example, suppose there is a steep grade eight miles from the power house. The current required at this point may be 200 amperes at 400 volts on the motors. By reference to the table the drop in the trolley and feeder is found to be 63 volts per 100 amperes, and 26 volts per 100 amperes in the rails, or a total of 178 volts for 200 amperes. If the station voltage is 550 there will be but 372 volts available at the car. To arrive at the proper size of feeder proceed as follows: The allowable drop is 550 minus 400 or 150 volts. Of this 52 volts is lost in the rails, leaving 98 volts for the feeder drop, or 49 volts for 100 amperes. Refering to the table the conductor in the eight mile column corresponding to this is 900 000 circular mils. We would then install a feeder of 900 000 minus 168 000 or 732 000 circular mils for eight miles and 532 000 circular mils for the remaining distance.

This calculation assumes that the trolley and feeders are connected at every point; however, it is customary to tap in feeders approximately every half mile or oftener. This limits the distance that the trolley alone will have to carry the total current.

SHOP EXPERIENCE

ITEMS FROM THE NOTEBOOK OF AN APPRENTICE

THREE-PHASE TRANSFORMATION WITH THREE AUTO-TRANSFORMERS

It is sometimes desired to transform three-phase current from 200 volts to 100 or 400 volts. If two-to-one transformers are not available, one winding of each of three transformers may be used as an auto-transformer connected as shown in Figs. 1 and 2 to give the desired transformation. The other winding of each transformer is not used.

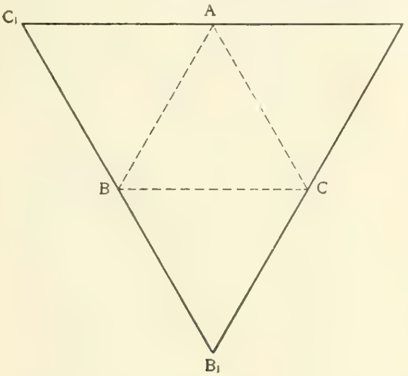


FIG. 1

In Fig. 1 each side of the large triangle represents one transformer winding having a tap at its middle point. This arrangement is simply the ordinary delta with taps at the middle points of the sides. Three-phase 200 volts impressed on A B C will give three-phase 400 volts on A_1 B_1 C_1.

Fig. 2 represents another way of accomplishing the same result. One end of each transformer winding is connected to the middle point of another transformer winding. Three-phase 200 volts impressed on A B C will give three-phase 540 volts on A_1 B_1 C_1 or a ratio of about 2.7 to 1.

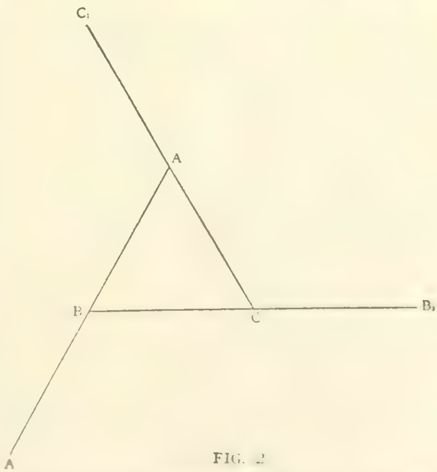


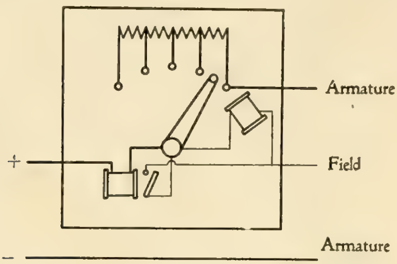
FIG. 2

In case three one-to-one transformers are available, connect the primary and secondary of each together, using these junction points as the middle points, A B C in the figures. If the transformers are provided with many taps the points A B C may be shifted from the middle positions and any ratio from two-to-one to one-to-one may be obtained with con-

nections as shown in Fig. 1. In Fig. 2 the maximum ratio, which may be three-to-one or even greater, is determined by the minimum triangle A B C that can safely take the impressed voltage.

MAXIMUM AND MINIMUM RELEASE STARTING RHEOSTAT

When a motor is located where an attendant seldom sees it, it is advisable to provide some automatic cutout device which will disconnect the motor in case the power goes off or a heavy overload is thrown on the motor, or in case the shunt field circuit becomes broken. The accompanying diagram shows the connections of a simple apparatus which gives this protection. The arm of the starting rheostat is sustained in the running position by a magnet excited by the motor field current. The armature current passes through a second magnet, which operates a small switch when the armature current reaches a certain predetermined maximum value. This switch short-circuits the sustaining magnet and the rheostat arm is restored to its off position by a spring.



A MAXIMUM AND MINIMUM RELEASE STARTING RHEOSTAT

EDITORIAL COMMENT

Difficulties in Getting On

I have re-read Mr. Swinburne's address twice since it was first called to my attention two months ago. I like its spice. Its effect is exhilarating. It shakes up things and people so artistically. One can really enjoy having his own notions upset now and then if it is done in such a happy way—and other people are being bumped at the same time.

Mr. Swinburne shifts our point of view and gives us engineers something to think about. We get a better perspective. Possibly I would not endorse all the propositions nor second all the advice if I were called upon to give them judicial sanction. Probably the flings at the theoretical professors and the laudation of the practical business men might lead a casual reader to think he should forget teaching and books and enter business pure and simple. But that is not the meaning. He says that text book science is of priceless value, but that knowledge is of

no value unless it will be useful. The caustic criticism of science teachers does not apply to many of the energetic and active young professors in America (and this "America" includes Canada), who are turning out a good product of embryo engineers. But young engineers are wont to think too highly of their learning, to overesteem scientific knowledge and to overlook common sense. Hence the emphasis to change the point of view.

Grant that in the past the business man has been unscientific and the engineer has known little of business, is that condition to continue? Are not industrial changes bringing about new conditions? Is it not becoming more and more essential that many business men have a personal engineering knowledge of the properties which they direct? Does not business as it changes from buying and selling to manufacturing and operating, as it is doing to-day, need engineering men and engineering methods, and are not men who have engineering education and experience coming more and more to the front as managers?

But the pendulum must not swing too far. We cannot all be business men, nor even business engineers. The fields of scientific research, of engineering instruction and of design and pure engineering give fertile promise to able men. It is better to be a good "theoretical" man, than a poor business man.

CHAS. F. SCOTT

Vacuum and Superheat

The discussion on turbine plant practice appearing on another page of this issue will serve to bring out prominently one phase of steam turbine work which has been given but little attention in the technical press.

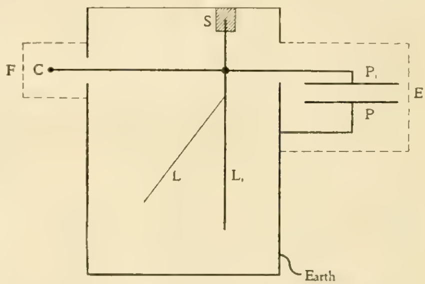
Although the graphical method of showing the net economy to be derived from bettered operating conditions is believed to be broadly applicable to any power plant, it must, of course, be borne in mind that no definite set of conditions can possibly be chosen that will cover all cases. The method outlined is simply a method, not a fixed rule, and every specific case must be determined on its own merits. The necessity for this is apparent in the number of variables entering into the question: on the one hand, saving of water and coal and possibly some steam plant capacity; on the other, loss from increased power requirements on condenser, heat supplied to superheater, and increased capital charges in the additional equipment. In all its phases the subject is a typical engineering problem.

RADIUM

REPORT OF LECTURE BEFORE THE ELECTRIC CLUB, FEBRUARY 10

BY PROF. HENRY A. PERKINS

On the evening of February 10th, 1905, Prof. Henry A. Perkins, of Trinity College, Hartford, Conn., delivered a lecture, the subject of which was radium, before an unusually large gathering of club members and their friends. In introducing his discussion of the subject itself, the lecturer stated: "Since M. Henri Becquerel, in 1896, first observed the curious properties possessed by a certain uranium salt (the double sulphate of uranium and potassium), that it could fog a photographic plate through black paper, the extraordinary energy and industry that have been displayed in investigating the class of phenomena known as radio-activity is unparalleled in the history of science. In just nine years this whole field of discovery has been tirelessly explored and a bewildering mass of material laid bare, part of which has been beautifully co-ordinated, while part still awaits some Newtonian mind to gather into a sweeping generalization the many heterogeneous effects and phenomena, as Keppler's law simplified the complex phenomena of the heavenly bodies."



A SPECIAL FORM OF THE ELECTOSCOPE FOR MEASURING THE ACTIVITY OF RADIUM

Prof. Perkins then gave a detailed account of the circumstances leading up to the discovery of polonium and radium by M. and Mme. Curie in 1898, pointing out the great difficulty involved in obtaining the metals from the compounds in which they exist as elements.

Aside from the peculiar physical properties of radium, its radio-activity is the quality which particularly characterizes this metal. "The activity of radium is measured by comparing it with uranium, calling the latter unity. Measured by this standard the highest figure given for pure radium chloride is 1 500 000, though, owing to inherent difficulties in measuring such high activity, this figure can only be regarded as approximate. This activity is shown first, and foremost, in its property of ionizing gases, that is, in making them conductors of electricity, and it is this property that affords the best means of measurement and detection." Radium also has optical, actinic, physiological and thermal qualities, all of which were described in detail.

The lecturer brought out some especially interesting points from an electrical standpoint in his discussion of methods of measuring the magnitude of ionization of air effected by the presence of a radium salt.

"In making a determination of the degree of ionization and the activity of the material, two classes of instruments are resorted to, the electrometer and the electroscope. If an electroscope is to be used, the ordinary gold leaf one will do very well, but a more delicate form is shown in the diagram. The active material is placed on P. The gold leaf L is charged by means of the knob C, which can be touched with a rubbed ebonite rod. The box is connected to earth. As soon as the air between P and P_1 is ionized, the charge on L and L_1 leaks across to P and the rate at which L collapses measures the current and hence the ionization. If comparative values are desired, a comparison of rates is all that is necessary, but if an absolute measurement of current is wished, one must know the capacity of the instrument. The capacity of such a system as that shown is not far from 0.33×10^{-20} farads, and if this rate of collapse indicates a decrease of potential of say 1 volt in 10 hours, the current i equals $\frac{CV}{t}$ equals about $5. \times 10^{-17}$ amperes, which is quite a possible case. Such an arrangement is thus capable of measuring a current much smaller than could be detected by the most delicate galvanometer. It can be readily shown that such an instrument can measure a current to correspond to the production of one ion per cubic centimeter per second, or even slower rates of production. The amount of radium necessary to produce this rate of ionization is so minute that the most refined chemical methods would fail to detect its presence. Thus in the case of radium a means of analysis is available, vastly more delicate than any yet devised by the chemists."

Prof. Perkins then showed in detail results of investigation concerning the various rays which are emanated from radium. One distinguishing characteristic between the different kinds of rays is the effect produced when they are passed through a magnetic field at right angles to the lines of force. The so-called Alpha rays are unaffected in direction by the magnetic field, while the Beta and Gamma rays are deflected in direction on one side or the other of the normal.

"Each particle of what are known as the Alpha rays, has a kinetic energy of 6×10^{-6} ergs, and it has been shown that one gramme of radium emits 10^{11} Alpha particles per second, thus one gramme emits energy by means of the projected atoms alone, at the rate of 6×10^{5} ergs per second, and 17 grammes are continually producing one watt of power, so that only 28 pounds are necessary for a continuous production of one horsepower. Of course, there is a gradual loss of power, but it will still be half the above after 1 500 years, and if we consider the total amount, the energy latent in one pound of radium, as derived from actual measurements of the rate of heat production, is appalling, being somewhere in the neighborhood of seven million horsepower hours, enough to drive one of the largest and fastest ocean steamers across the Atlantic and back again."

The lecturer left a most striking impression of the enormous field and the complexity of the problem presenting itself to investigators of these very active metals, and the theoretical discussion of the various

properties of radium which Prof. Perkins dwelt on was particularly interesting on this account.

The lecture was brought to a conclusion by this statement: "Attempts to render ordinary matter radio-active and so realize the alchemist's dream, are so far fruitless. J. J. Thompson is now at work on that very problem in the Cavendish laboratory, some of his attempts being made along the line of cathode bombardment, but so far without success. This is now, perhaps, the most important problem in the study of radio-activity, and there seems to be every reason to hope for ultimate success. As Schuster has said: 'No kind of matter is altogether devoid of every property possessed by all other kinds,' and if all elements are not radio-active, at least in a slight degree, this rule would be violated for the first time in the knowledge of science. Hence it is only a step to argue that if this property is possessed in minute degrees, why should it not be possible to discover a way of hastening its action? And in spite of the fact that even radium so far resists all attempts to either hasten or retard its rate of decay, we may yet master the secret that shall place at our disposal the immense energetic resources of the very stones we walk on."

Prof. Perkins showed some very interesting diagrams by means of lantern slides, and also performed some experiments which showed the effect of a radium salt in ionizing air. These added very materially to the interest of the lecture.

A SINGLE-PHASE RAILWAY, WITH DOUBLE CATENARY TROLLEY LINE SUPPORTED IN SPANS OF 300 FEET BY STRUCTURAL STEEL BRIDGES. THE CONSTRUCTION PROVIDES FOR THREE TRACKS, BUT ONLY ONE TROLLEY HAS YET BEEN COMPLETED

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SINGLE-PHASE LINE CONSTRUCTION

By THEODORE VARNEY

THE introduction of the single-phase system for railway operation renders possible the use of high voltage directly on the conductor supplying the cars with power. With this increase in voltage, a tremendous saving in cost of copper is obtained

A SINGLE CATENARY TROLLEY. SUPPORTING BRACKET IS OF PIPE CONSTRUCTION

but the insulation of the supply system must be improved in proportion to the increase of pressure.

The liability of personal injury and damage to property resulting from depreciation of the supply system or unavoidable accidents to rolling stock must be carefully guarded against.

The third rail which has heretofore been almost exclusively used for heavy traction work is impracticable for use with high voltages, both on account of difficulty in insulating a conductor so close to the ground and also because of danger to life. Its use in

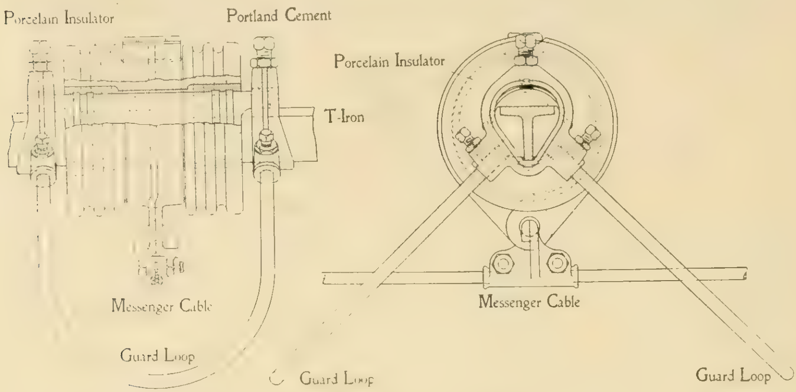


FIG. I—PORCELAIN INSULATOR, SHOWING METHOD OF ATTACHMENT AND GUARD LOOP

terminal yards is out of the question. The overhead conductor is, therefore, unquestionably the most practicable. The present paper will describe some of the features which have been developed with the view of combining in this system a thoroughly safe and reliable operation with the minimum cost.

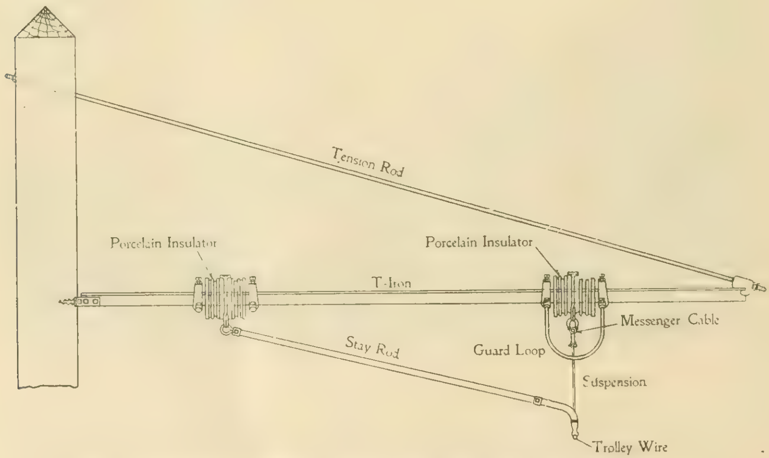


FIG. 2—T-IRON SUPPORT, WITH STAY ROD, FOR USE ON CURVES

The first question for consideration being the insulator, it is necessary to choose a material which would stand a high voltage

test, and also be unaffected by water, corrosive influences such as sulphur smoke, or become softened with the heat of the sun.

Porcelain fulfills these requirements more nearly than any other available material and it has the further advantage of indicating in most cases, by inspection, whether or not it is defective.

The most familiar porcelain insulator is the type which is screwed on to a pin and carries the wire in a groove in its top. This design, while effective electrically, is poor mechanically. The shape finally adopted is a corrugated porcelain cylinder about six inches long and six inches in diameter with a three inch hole through its axis and a groove about one-half inch deep about its center. This porcelain is cemented on a malleable iron sleeve fitted with clamps by means of which it is secured to the bracket arm. The voltage necessary to break the insulating surface of the insulator is 40 000. The clamps of the mounting sleeve are provided with lugs into which loops are inserted for the purpose of protecting the porcelain against accidental breakage by reason of a wheel trolley flying off the wire under the porcelain. Fig. 1.

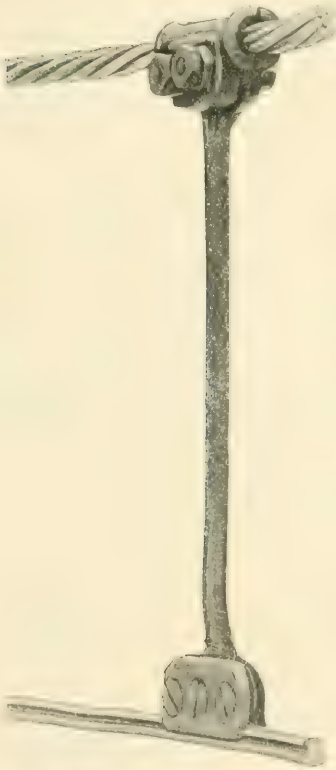


FIG. 3—HANGER FOR SUPPORTING THE TROLLEY WIRE FROM THE MESSENGER CABLE

The insulator can be used with the ordinary pipe bracket arm, but a simple and more effective one has been devised of T-iron. It consists of a single straight piece of T-iron fitted at the pole end with lugs which partially embrace the pole and are bolted to it with lag screws. At the outer end a tension rod is attached, the upper end of which passes through the pole and is held by a nut and washer on the rear. Fig. 2.

The hangers are made of malleable iron and are clamped to the suspension or messenger cable by means of bolts and to the

trolley wire with screws. They are spaced ten feet apart and are of varying length so as to hold the trolley wire horizontal. By this means the possibility of breakage of the trolley is materially reduced, while if it should break, the ends could not come dangerously near the ground. The hanger is shown in Fig. 3.

The steel messenger cable is 7/16 inch in diameter and composed of seven strands. Its breaking strength is 6,000 pounds.

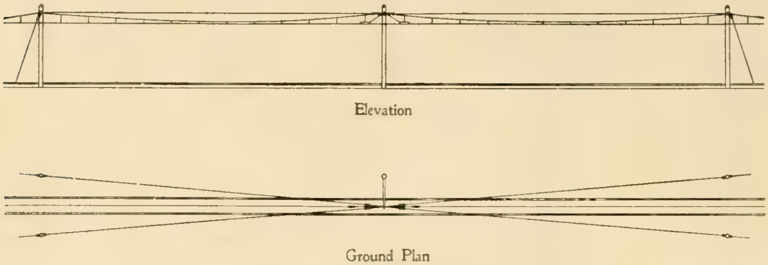


FIG. 4—GENERAL ARRANGEMENT OF ANCHOR WIRES

The messenger cable is supported from the insulator by a malleable iron collar having an eye in its lower side into which the messenger clamp hooks. The messenger clamp is bolted to the cable and prevents lengthwise motion but affords considerable flexibility, thereby preventing wear on the cable or shock to the porcelain. The messenger cable also passes through the guard loops which adds a further precaution against the cable coming down. Fig. 1.

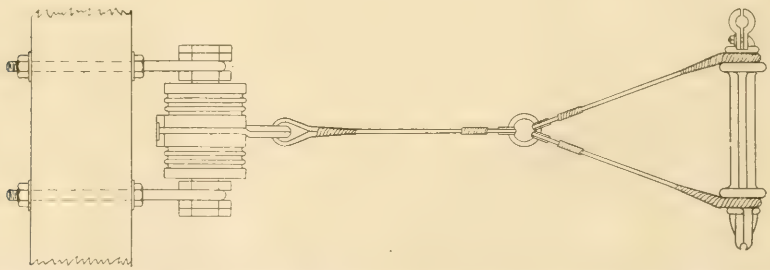


FIG. 5—A STRAIN INSULATOR AND THE METHOD OF ATTACHING PULL OFF WIRES

This method of suspension enables the trolley and messenger to be run out along the track and pulled up into place in reel lengths without the necessity of fishing the cable over the bracket arms.

The trolley wire is of No. 000 hard drawn copper wire grooved in section and the hangers are fitted with turned-in edges which clamp into the groove. The hangers being close together and stiff,

prevent any twisting of the trolley wire and the finished construction presents a level, firm surface over which a high speed trolley may pass with the minimum of vibration.

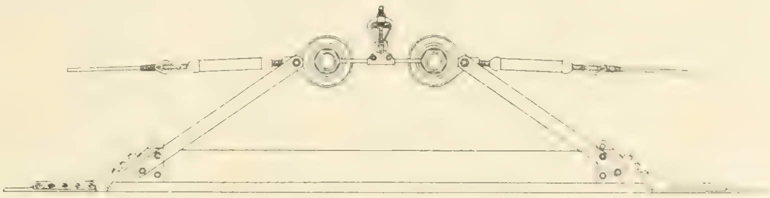


FIG. 6—A WOODEN SECTION BRAKE

The length of span on straight track is 120 feet, but is shortened on curves where steadying devices shown in Fig. 2 are used to hold the trolley wire under the messenger. The minimum cold

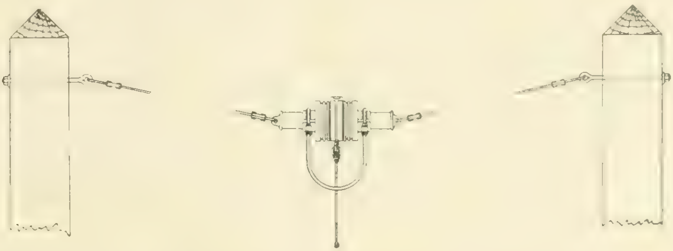


FIG. 7—SUSPENSION SUPPORT FOR THE CATENARY LINE

weather sag in the messenger is 11 inches in 120 feet, corresponding to a tension of 2 000 pounds. In hot weather the sag increases but slightly.

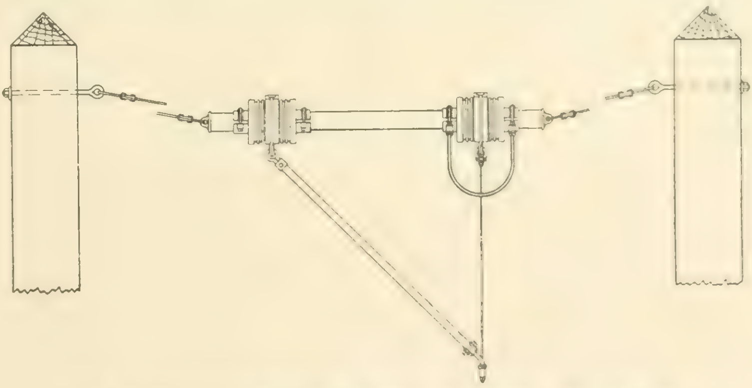


FIG. 8—SUSPENSION SUPPORT FOR THE CATENARY TROLLEY LINE USED ON CURVES

Anchors are used at tangent points of curves and at intervals

of about one mile. The general arrangement is shown in Fig. 4 and the strain insulator is shown in Fig. 5.

For curves of short radius, the arrangement shown in Fig. 5 is used. The disposition of the pull-off wires is such that by a proper adjustment of their length the messenger and trolley can always be held in a vertical plane.

At sub-stations and other points, section break insulators are necessary and the construction shown in Fig. 6 is used. The break in the trolley wire is made by inserting a strip of treated wood.

For places where the bracket arm construction cannot be used, cross spans may be employed and Figs. 7 and 8 illustrate the arrangement.

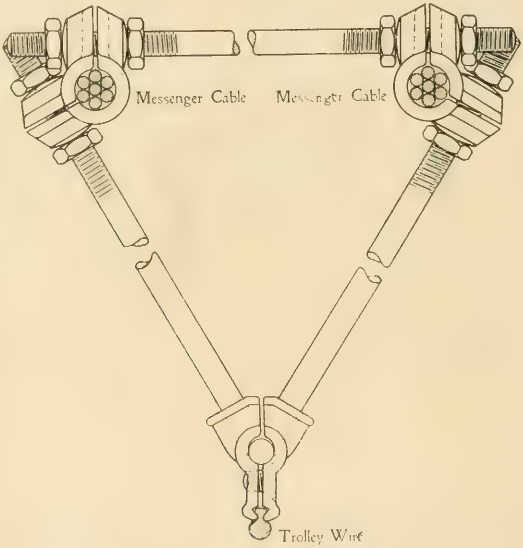


FIG. 9—A TRIANGULAR HANGER USED WITH THE DOUBLE CATENARY CONSTRUCTION

Thus far, the simpler form of construction—using wooden poles has been considered. For heavier service where more than one track is usually employed and higher voltages would be used, more substantial construction is advisable. Iron should be used for the supports which should be of substantial design and as few in number as possible, consistent with proper stability. For this purpose a system has been designed employing structural iron bridges or towers spanning the tracks at intervals or 300 feet. Upon these bridges are strung steel cables and in this case two catenary messenger cables are used to render the long spans stiffer. These cables

are of high grade steel and are 5/8 inch in diameter. The trolley wire is hung from these cables by means of triangular hangers spaced 10 feet apart. Fig. 9.

Five miles of the wooden pole construction and 2 500 feet of the iron bridge work have been completed at East Pittsburg and have been in operation for several months. Under the heavy snow laden conditions shown in the frontispiece, the leakage of the entire line, five miles in length, with 6 000 volts was one ampere.

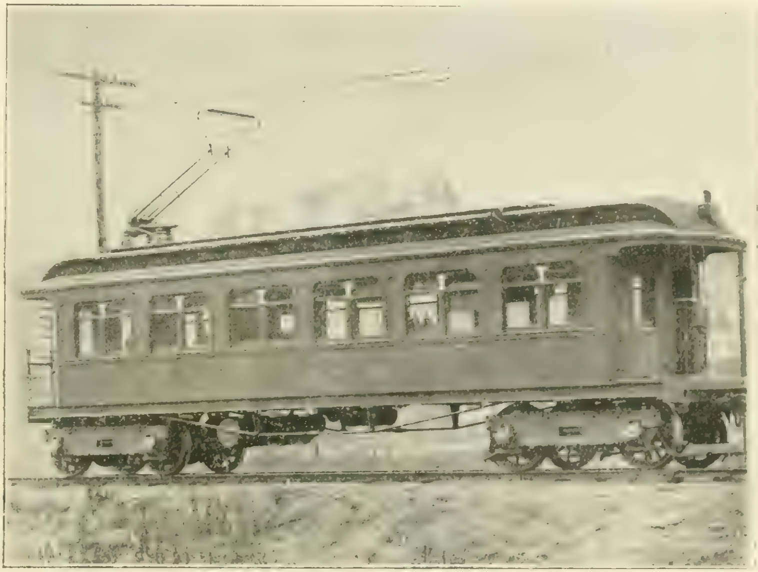
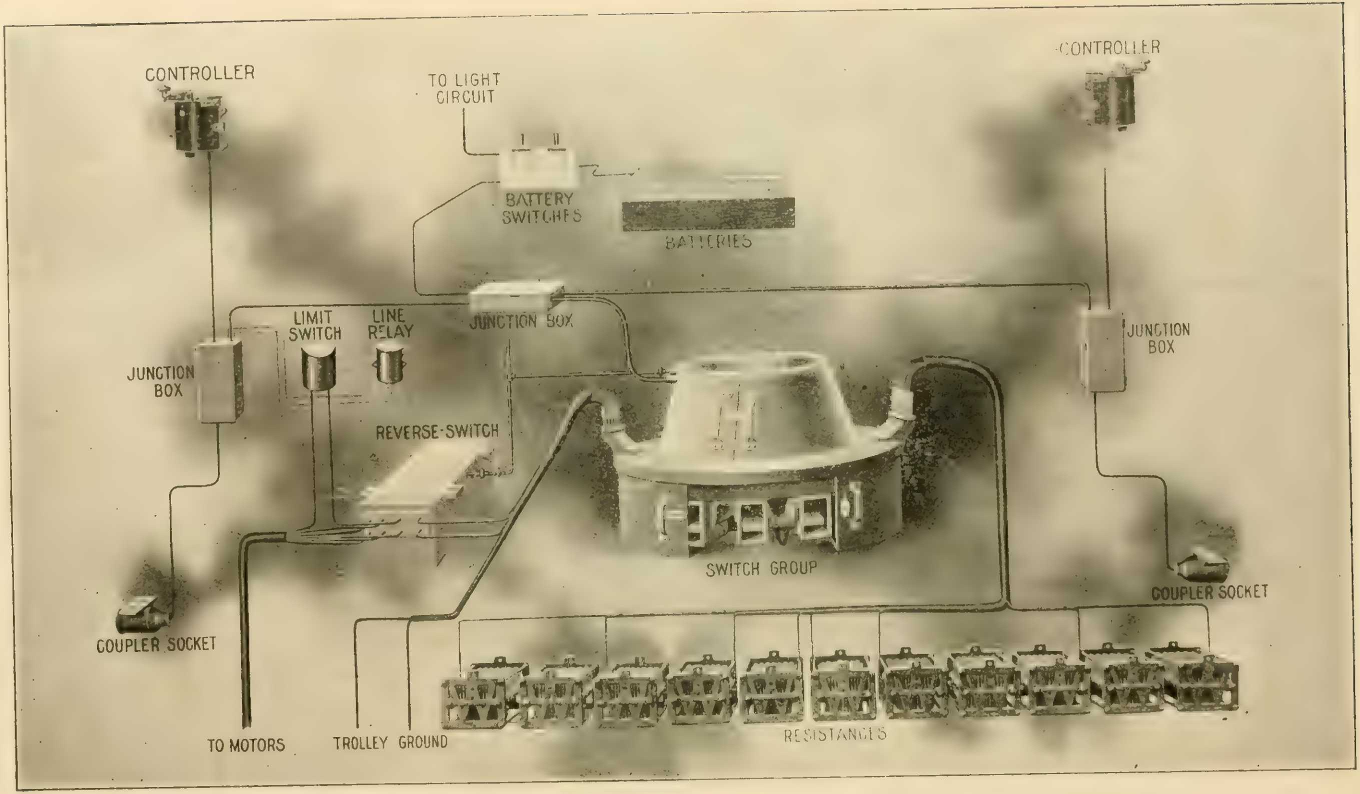


FIG. 10—A SINGLE-PHASE RAILWAY CAR EQUIPPED WITH A PNEUMATICALLY-OPERATED BOW TROLLEY

The use of high voltages and high speeds requires a trolley which can be operated without the use of a rope. For this purpose several designs of air operated trolleys have been developed. Fig. 10 represents one of these forms, which uses air for raising and lowering and relies upon springs to take care of the variation in height. It may be run in either direction at high speed without coming off the wire. It is fitted with a metal shoe six inches wide and supplied with grease grooves for lubricating the trolley.

The frame is insulated from the car roof by porcelain pillars and the air connection is insulated by a rubber hose coupling.

The trolley is raised and lowered by air pressure, controlled by a valve in the motorman's cab.



ARRANGEMENT OF THE CONTROLLING APPARATUS AND CONNECTIONS ON EACH MOTOR CAR

THE ELECTRO-PNEUMATIC SYSTEM OF TRAIN CONTROL

By P. C. McNULTY, Jr.

TO handle the enormous travel in and around the large cities, trains operated by electricity are being run, some by means of electric locomotives and others by multiple control. The use of electric locomotives is readily understood by its similarity to the steam locomotives. Several motors are here mounted on the trucks of a single car, which car furnishes all the power to draw the entire train. By multiple control is meant the operation of a train of cars all or at least a large number of which are motor cars. To do this it is at once apparent that some system must be provided whereby all the motors throughout the train will be controlled in perfect unison and by a single motorman. Distributing the tractive powers throughout the train greatly increases the flexibility of operation. A better schedule can be made which means both greater accommodation to the traveling public and greater earnings to the road.

Every system of multiple control consists, in general, of motor controlling devices located beneath each motor car as a part of the motor equipment and an operating circuit which connects the motor controlling device on a car to the small controller on the platform at each end of the car. The train may be controlled from any one of these controllers, but the one in the front cab of the first car in the train is, of course, the one generally used.

In the present system of running single cars the motor controlling switches are operated by hand. In a train these switches must obviously be operated by some intermediate means. In the systems now in practical operation this is done either magnetically by solenoids or electro-pneumatically by air pressure controlled by magnetically operated valves.

It is the purpose of this article to describe the latter system, which has been developed by the Electric Company.

The characteristic feature of the Westinghouse electro-pneumatic system is the operation of the switches for controlling the motors by means of compressed air from the braking system. The air cylinders, when closing the switches, operate against powerful springs, so that when the air pressure is removed the springs will

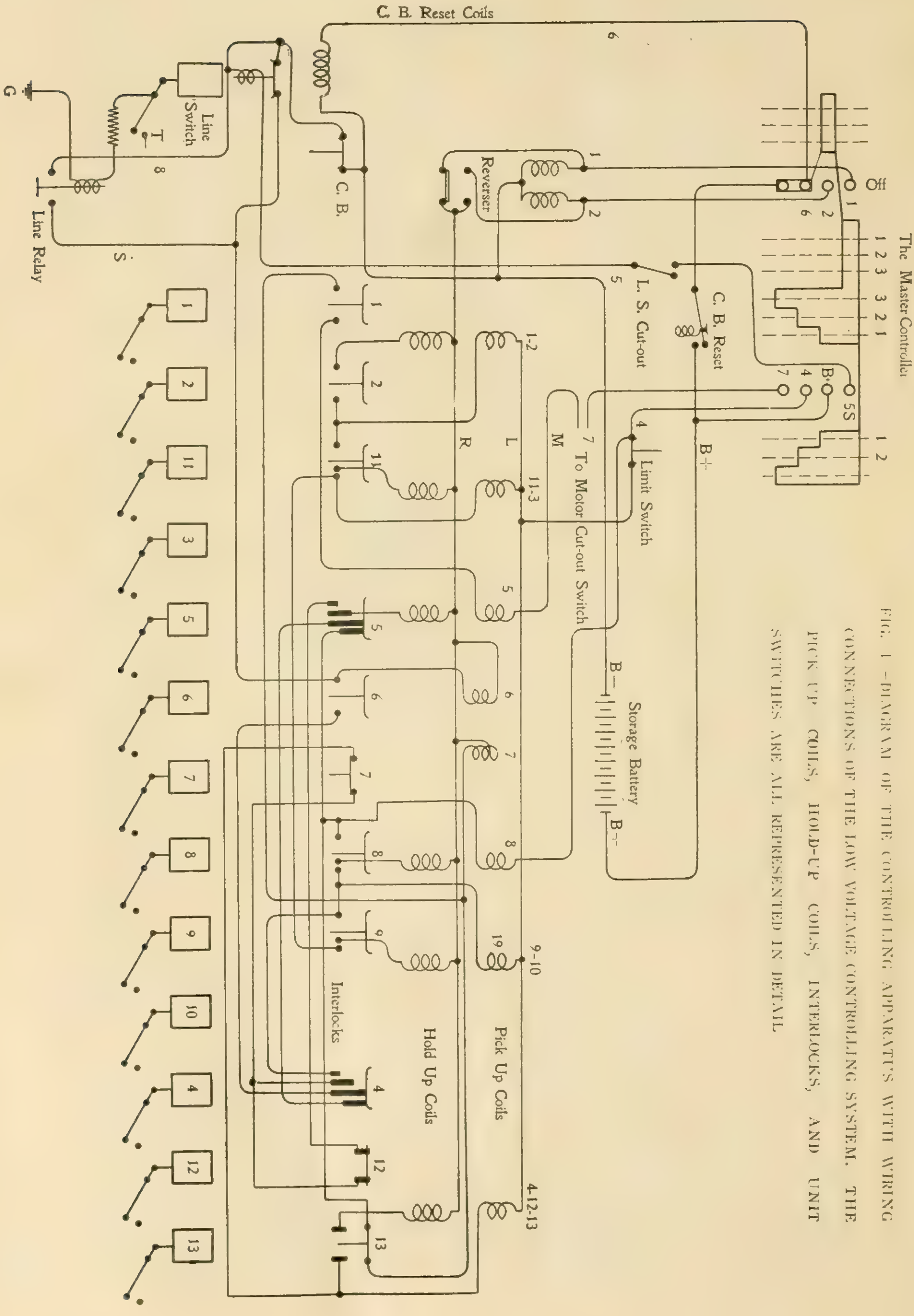


FIG. 1—DIAGRAM OF THE CONTROLLING APPARATUS WITH WIRING CONNECTIONS OF THE LOW VOLTAGE CONTROLLING SYSTEM. THE PICK UP COILS, HOLD-UP COILS, INTERLOCKS, AND UNIT SWITCHES ARE ALL REPRESENTED IN DETAIL

quickly open the switches. The cylinders are of generous size and the air pressure is seventy pounds per square inch, thus allowing the opening spring to be very strong, insuring a positive and reliable opening of the switch. The admission and release of the air is governed by electrically operated valves, the current for which is supplied at 14 volts by a storage battery. The entire operating circuit being at this low voltage gives the system several advantages, the more important of which are: Independence of the main circuit; low operating and maintenance cost, and safety to passengers and operators, since the currents at line voltage are in no case carried above the floor of the car.

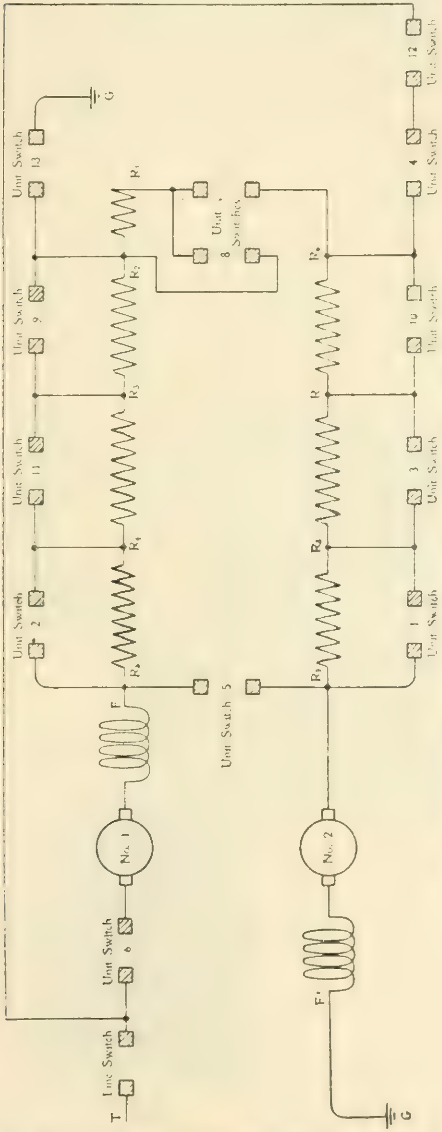


FIG. 2—WIRING DIAGRAM OF THE MOTOR CIRCUIT ON EACH CAR

THE TRAIN CIRCUITS

There are two separate and distinct circuits on the train. These are:

(1) The low-voltage operating circuit.

(2) The high-voltage motor circuit.

The operating circuit is shown diagrammatically in Fig. 1 and is fed from storage batteries, one set on each car, at a pressure of 14 volts. This circuit is used to energize small electro-magnets, thus opening the valves that

admit the compressed air to the main switches of the motor circuit. This is the only circuit that must be established from car to car and is the only one that is brought into the body of the car.

The motor circuit, shown in Fig. 2, is an independent circuit on each car. It is at line voltage and is the same as the circuit on the ordinary trolley car, except that the series-parallel controlling device is beneath the floor of the car instead of in the motorman's cab.

THE MASTER CONTROLLER.

A small controller known as the master controller, shown in Fig. 3, is placed in the motorman's cab at each end of every motor car of the train. As previously stated, the controller in the front end of the first car is used to control the train, and all of the current for the operation of all the switches on the train passes through this one controller, but the current for the switches on each motor car is obtained from the battery thereon; thus, as is more fully explained later, the number of cars composing a train is unlimited.

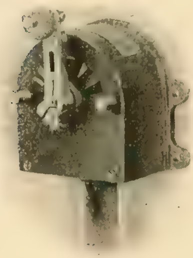


FIG. 3—THE MASTER CONTROLLER

The master controller handle has three positions for each direction of movement, the off position being in the center. These are:

(1) The switching notch.
(2) The series running notch.
(3) The multiple running notch.

When the handle is turned without stop to the multiple running position, the car will start and build up to speed, with the full line voltage on the motors, at a uniform acceleration and without current interruption to the motors. If the hand is removed from the handle, it is at once brought to the off position, thus opening all of the switches.

THE LIMIT SWITCH

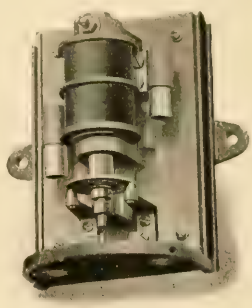


FIG. 4—THE LIMIT SWITCH

The rate at which resistance is cut out of the circuit is such that the accelerating circuit is practically uniform. This is accomplished by the use of a limit switch, shown in Fig. 4. This feature is very valuable as it gives a smooth and economical ac-

celeration and prevents abuse of the equipment by throwing on the power in excess of a predetermined rate.

This switch consists of a small solenoid in series with one of the motors. When the current rises above a predetermined limit, the armature of the solenoid is raised against gravity, thus lifting a disc off of two contacts in the operating circuit. The switches that are already in are held in, but no other can come in until the current falls off enough to let the disc down on the contacts again.

THE SWITCH GROUP

A controlling device, shown in Fig. 5, often spoken of as the turret controller—from the shape of its cover—is placed beneath the floor of the car. Its proper name is the switch group and it consists of 13 independent or unit switches grouped radially around a large and powerful blow-out coil. By reference to Fig. 6, which is a ver-

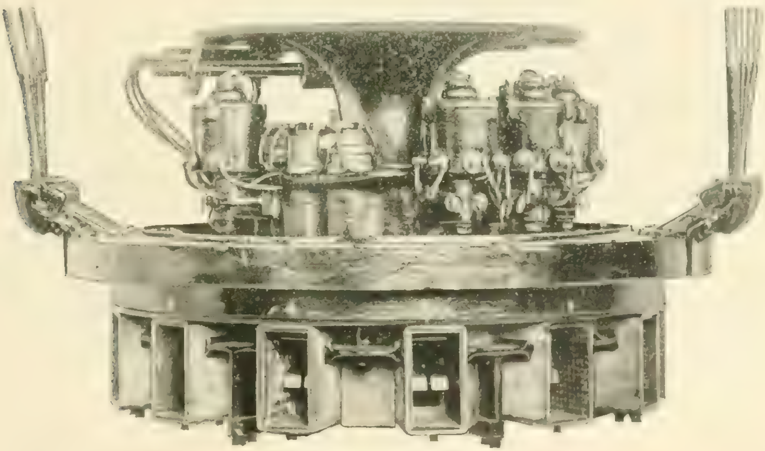


FIG. 5—THE SWITCH GROUP

tical section through a switch group, there will be seen a large air chamber just above the blow-out coil and in the center of a casting which is bolted to the supporting frame. In this casting, directly above the inner end of each unit switch, is an air cylinder and upon the outer edge of this cylinder casting are bolted eight iron-clad thoroughly protected magnet valves. When the magnet is energized its armature is lowered; this opens a valve and allows the air to pass from the air chamber to the cylinder, the air being supplied at a pressure of 70 pounds per square inch from an auxiliary air tank fed from the main braking tank. On its downward stroke the piston com-

presses a strong spring and closes its unit switch. The cut shows a switch and piston in this position. When the circuit around the magnet is opened, the valve closes and opens the exhaust to the atmosphere. The piston is then forced up by the compressed spring under it, opening the switch. On the upper end of the piston rod is a small metal drum and, as the piston moves downward, this drum makes or breaks the connection between the small fingers surrounding it, as shown in the cut. This closes or opens the circuit to the magnet of the next switch, thus closing or opening the switch. This is called the interlock and it will be readily seen how resistance may

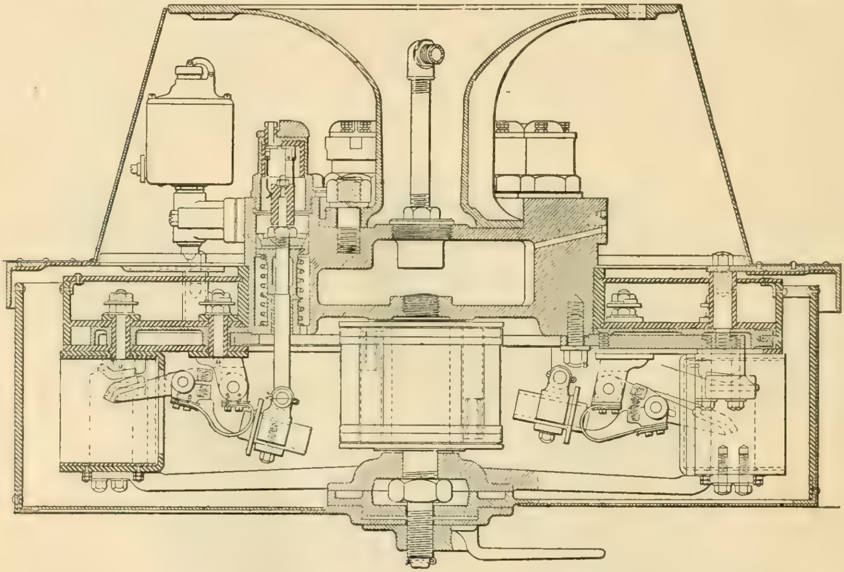


FIG. 6—VERTICAL SECTION THROUGH THE SWITCH GROUP

be automatically thrown in or out of the motor circuit, since each unit switch shunts a block of resistance.

By reference to the cut it will be seen that the switch arm carries contact fingers that are pivoted on the arm. A small spring under the inner end of these fingers compresses as the two contact tips engage, thus causing a wiping or rocking motion of the fingers, which maintains a positive contact and upon which the wear is a minimum. The studs for the motor leads are supported by a plate that is bolted to the cylinder casting. These studs are insulated from the plate and with the connecting wires are enclosed in a tight insulating box, protecting them from dust and moisture, with sealed outlets for connection to the car wiring.

The supporting plate just referred to forms the upper part of the magnetic circuit for the blow-out coil. The lower part of this circuit is completed by a cast iron spider with T-shaped pole tips.

The switch group is enclosed in a turret-shaped sheet-iron cover, easily removable for inspection, which effectually protects the contacts from dust and moisture. The lower part of the cover is made in halves, each capable of rotating, one inside the other.

The normal position of all the switches is open and any failure of the air supply or interruption of the operating circuit opens all the unit switches. The switches never stick or weld from heavy currents, because they are opened by the strong spring under the piston previously referred to.

THE WIRING DIAGRAMS

The diagrams referred to below in connection with the explanations in the following paragraphs, illustrate the electric circuits that are established on one car or a train of cars equipped with the electro-pneumatic control and by means of them it is possible to trace these circuits and determine the results produced by each movement of the master controller.

The diagram, shown in Fig. 2, gives all of the electrical connections in the line-voltage circuit between the trolley, the line switch, the motors, the switch group and the resistances on a single car and shows how the unit switches vary the voltage on the motors by cutting out or connecting resistance.

Fig. 1 shows all of the electrical connections between the various pieces of apparatus in the low voltage circuit which operate the high voltage switches of a single car.

Fig. 7 shows the electrical connections that must be established to operate two or more cars from one master controller.

These diagrams will be taken up in the order just given to illustrate, first, the functions of the unit switches of the switch group on one car, then to show how these switches are made to perform their functions and, finally, to show the effect of operating more than one car from one master controller.

Each explanation is divided so that the circuits established on each notch of the master controller may be traced.

With the master controller in the off position a circuit is closed around the circuit-breaker reset coil as soon as a small knife switch, shown as the circuit-breaker reset in Fig. 1, is closed. The closing

of this switch sends a current as follows: $B+$ through fingers No. 3 and No. 6 of the master controller, thence around the circuit-breaker reset coil to $B-$. This closes the circuit-breaker trip, shown as *CB* in the sketch. The master controller handle may now be turned one way or the other to test the air and the electrical connections of the operating circuit.

If the small knife switch, called the line switch cut-out, be closed, a circuit may be established as soon as the master controller is turned to the first position, that will close all of the line switches on the train. The following paragraphs show the results of turning the master controller to other positions.

THE MOTOR CIRCUIT

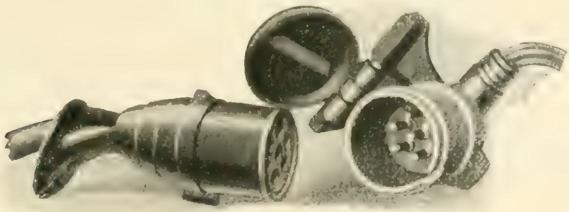
The Switching Notch—When the master controller is turned to the first notch, the line switch and reverser are closed; then, switches Nos. 6 and 7 of the switch group are closed, as explained later, and the first flow of current through the motors is as follows: From trolley, Fig. 2, marked *T* through the line switch; No. 6 switch and No. 1 motor; thence, through resistances R_5 to R_1, to No. 7 switch, through this switch to R_6, then through resistances R_6 to R_9, thence through No. 2 motors into the ground return. Thus the motors are put in series with all of the resistance in the circuit.

MASTER CONTROLLER—COVER REMOVED

The Series Running Notch—When the master controller is turned to the second notch, the No. 8 switch of the switch group closes; then the circuit described above will pass through this switch, thus shunting R_1 to R_2 and raising the voltage on the motors. The closing of No. 8 switch causes switches 9 and 10 to close; this closes switches Nos. 11 and 3, and they, in turn, close switches Nos. 1 and 2. This action is fully described later. As may be seen from the diagram, each switch as it closes shunts a block of resistance so that when all of the switches named above are closed the motors are in full series and the flow of currents is as follows: From trolley through the line switch, No. 6 switch and No. 1 motor, thence through switches Nos. 2, 11, 9, 8, 7, 10, 3 and 1 in the order given,

then through No. 2 motor and into the ground return. The motors are now running in series with no resistance in the circuit and the change over to the parallel may be made.

The Multiple Running Notch.—When the master controller is turned to the third position, No. 5 switch closes, thus causing switch Nos. 7, 8, 9—10, 11—3, and 2—1, to open simultaneously as described later. This causes a flow of current from *T* through the line switch, No. 6 switch, No. 1 motor, No. 5 switch, No. 2 motor and into the ground return. As the No. 7 switch opens, it causes switches Nos. 4, 12 and 13 to close. The No. 4 switch closing opens the No. 5 switch and the change from series to parallel has been made without breaking the circuit. The first circuits in multiple are established as follows: From *T*, through the line switch, No. 6 switch, No. 1 motor to R_5, thence through R_5 to R_2, then through No. 13 switch and into the ground return. Also from *T* through switches Nos. 12 and 4 to R_6, thence through R_6 to R_9, then through No. 2 motor and into the ground return. Switches Nos. 9—10, 11—3, 1 and 2 automatically close, as on the previous notch, as soon as the limit switch will allow, as explained later. Each switch shunts its resistance until, when all the switches are in, the motors are running in full multiple and the current is flowing as follows: From *T* through the line switch, No. 6 switch and No. 1 motor,



JUMPER CONNECTER

thence through switches Nos. 2, 11, 9, 13 and into the ground return. Also, from *T* through switches Nos. 12, 4, 10, 3, 1, then through No. 2 motor and into the ground return.

Thus it is seen that the motors on a single car are now in full multiple and controlled as one motor. Later it will be shown how the motors on every car of the train are controlled simultaneously as one motor.

THE OPERATING CIRCUIT

The Switching Notch—When the master controller handle is

turned to the first notch the line switch, line relay and reverser are closed. As soon as the interlock on the reverser closes, the switches Nos. 6 and 7 of the switch group are closed. This throws the two motors into series and brings all of the resistance into the circuit.

By reference to Fig. 1 it will be seen that the circuits which are established to close these switches are as follows:

From *B*+ of the battery to *B*+ in the master controller, then through 5*S* to the line switch cut-out, which has already been closed by hand, thence through 5 around the magnet on the line switch and back to *B*— through the circuit-breaker trip. This closes the line switch and the line relay and opens the interlock shown above the line switch.

At the same time the current flows from *B*+ to finger No. 1 or No. 2 on the master controller according whether the handle is turned in the forward or reverse direction, then around the magnet No. 1 or No. 2 on the reverser, as the case may be, and then to *B*—. This closes the reverser and as it closes its interlock closes, thus establishing the circuit marked *R*, from No. 1 or No. 2 magnet of the reverser to the magnet on No. 6 switch of the switch group.

From this magnet the current returns to *B*—, shunting the No. 6 interlock, through the line relay, and the circuit-breaker trip.

This closes the No. 6 unit switch, as described under paragraph, switch group, thereby closing its interlock and establishing a circuit through the magnet of the No. 7 switch as follows: *R* being energized and the interlock on No. 6 closed, as just described, the current flows from *R* through the magnet on No. 7 switch to No. 13 interlock, thence through interlocks Nos. 5, 4 and 6 to the line relay and through the circuit-breaker trip to *B*—.

This closes the No. 7 unit switch, thereby causing the current to flow through the motor circuit, as previously described.

The Series Running Notch—If the handle is turned to the second notch, No. 4 finger in the master controller is joined to *B*+, as may be seen from the sketch. This causes the switches No. 8, No. 9—10, No. 11—3, No. 1—2 of the switch group to close automatically in the order given. When these switches have all closed, the motors are running in series with all of the resistance out, as previously shown. From the diagram, it will be seen that current may now flow from *B*+ to No. 4 finger then shunting the limit switch to the magnet on No. 8 switch, around this magnet and through interlocks, No. 5, No. 4, and No. 6, to the line relay and through the circuit-breaker trip to *B*—, as described before. This closes the

No. 8 switch and, as its interlock closes, a circuit is established around the magnet on switches No. 9 and No. 10, as follows: From $B+$ through 4 to the limit switch, thence through L around magnet No. 9 and No. 10; then through interlocks 8-5-4-6 in the order given and to $B-$ through line relay and CB. This closes these switches which closes interlock No. 9. The closing of No. 9 interlock closes switches No. 11 and No. 3 in the same way and No. 11 interlock closes switches No. 1 and No. 2.

The diagram shows two windings on all of the magnets except No. 6 and No. 7. These windings are known as the pick-up coils and the hold-up coils respectively as marked in the sketch. It has already been seen that a circuit around the pick-up coil closes the switch, and reference to the sketch will show that as soon as the interlock or any switch is closed the hold-up coil is brought into the circuit that picks up switches Nos. 6 and 7. Then if the limit switch breaks the pick-up circuit, the switch that has closed is held in by the hold-up coil, but the next switch cannot pick up until the limit switch has closed again.

The Multiple Running Notch—When the handle of the master controller is on the third position the No. 5 switch closes and in so doing opens switches No. 7, 8, 9 and 10, 11—3, 1—2 as stated above. As the No. 7 switch opens its interlock closes the circuit around the magnet on switches Nos. 4, 12 and 13. These circuits are established as follows: From $B+$ to No. 7 finger of the master controller thence to the motor cut-out switch. From this switch through M to the magnet on No. 5 switch, thence through the interlocks 1-13-5-4 and 6; then through the line relay and CB to $B-$. This closes No. 5 switch.

The interlock on this switch is a special four point interlock and is so made that the circuit around switches Nos. 7, 8, 9—10, 11—3, 1—2 is broken as the switch closes and the circuit around the magnets on switches Nos. 4, 12 and 13 is established as soon as the No. 7 switch is opened. The interlock on No. 7 switch is a reverse order, that is when the switch is open the interlock is closed and vice versa. Therefore, when No. 5 switch opens No. 7 switch, as just explained, the interlock on No. 7 switch closes the following circuit around the magnets on switches Nos. 4, 12 and 13: From $B+$ to 4, thence through the limit switch through L to magnets No. 4, 12 and 13, thence through No. 7 and No. 12 interlocks to the low contact of No. 5 interlock, then to the high contact of No. 4 interlock, thence

through No. 6 switch, line relay and circuit-breaker to *B*—. This closes switches Nos. 4, 12 and 13. As the No. 4 interlock closes, it opens the circuit around No. 5 switch, thus opening this switch as soon as No. 4 switch is closed. The opening of this switch, with the closing of No. 4 switch, changes the motors from series running to parallel running as mentioned above.

If the current has not risen above the limit of the limit switch a circuit is established around the magnets on the Nos. 9 and 10 switches as soon as the No. 4 interlock is closed. If the limit switch is opened by the current rising above its limit, this circuit is not completed until the current has fallen enough to allow this switch to close and then the circuit is as follows: *B*+ to 4 through the limit switch; thence through *L* to No. 9 and No. 10 magnet, thence shunting No. 9 interlock to the low contact of No. 4 interlock; thence through No. 6 interlock, line relay and *CB* to *B*—. This closes switches Nos. 9 and 10 and they in turn close Nos. 11 and 3, which closes Nos. 1 and 2, as described on the series running notch.

THE TRAIN CONNECTIONS

The diagram shown in Fig. 7 shows how the wires of the operating circuit are connected

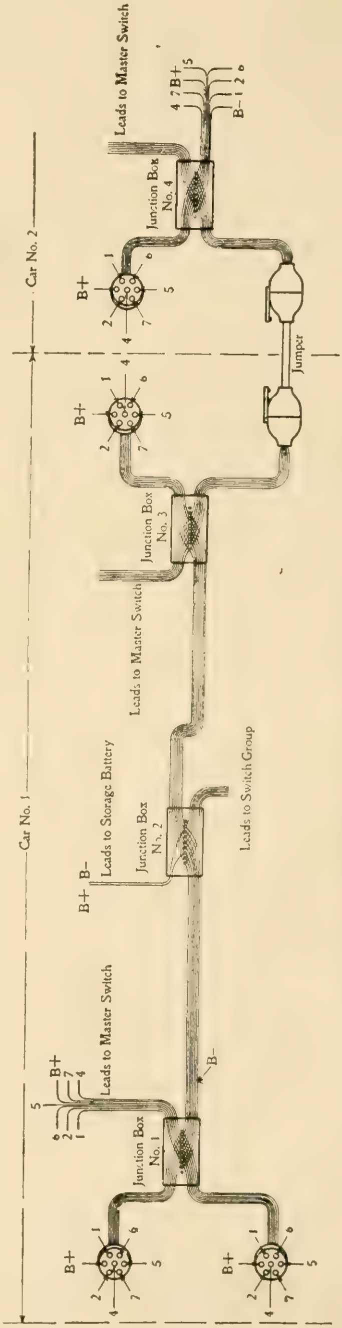


FIG. 7—DIAGRAM SHOWING THE JUMPER CONNECTIONS BETWEEN CA

from the master controller to the apparatus on a car and to the train cable by means of the junction boxes. The letters on the junction box terminals correspond with the letters on the circuits that were described in the operating circuit.

This train cable consists of seven of these 14-volt wires, as shown in the sketch, and runs throughout the length of the train. The connection from car to car is made by means of a jumper.

Thus it is seen that the apparatus on each car is really paralleled on to this train cable and it illustrates, as was mentioned be-

CAR EQUIPPED WITH ELECTRO-PNEUMATIC SYSTEM OF TRAIN CONTROL.

fore, how the total current for operating all of the switches of the train must pass through the master controller that controls the train, but the current for the apparatus on each car is furnished by the battery thereon. This explains how all the motors on the train are made to act simultaneously and uniformly and shows that, by distributing the power throughout the train and using multiple control, the train may be started with smoothness and rapidity.

HOW TO REMEMBER THE WIRE TABLE

By CHAS. F. SCOTT

THE wire table for the B. & S. gauge copper wire has a few simple relations, such that if a few constants are carried in the memory the whole table can be constructed mentally with approximate accuracy.

RESISTANCE—A wire which is three sizes larger than another wire has twice the weight and half the resistance.

No. 10 wire has a resistance of 1 ohm per thousand feet; No. 7 wire, which is three sizes larger, has .5 of an ohm per thousand feet; No. 4 wire, which is three sizes larger than No. 7, has .25 of an ohm; No. 13 wire, which is three sizes smaller than No. 10, has 2 ohms; No. 16 wire, which is three sizes smaller than No. 13, has 4 ohms. It is easy, therefore, knowing the resistance of No. 10, to find the resistance of No. 7, No. 4, No. 1 and No. 000; also of No. 13, No. 16, No. 19, etc.

A wire which is ten sizes larger than another wire has ten times the weight and one-tenth the resistance.

As the resistance of No. 10 is 1 ohm per thousand feet, the resistance of No. 0 is .1 of an ohm, and the resistance of No. 20 wire is 10 ohms. As the resistance of No. 4 is .25 of an ohm, the resistance of No. 14 is 2.5 ohms and of No. 24, 25 ohms.

In the following table the first column contains the sizes of wire which differ from one another by three sizes. The resistance of each wire in this column is seen to be twice that of the next larger

Size.	ohms.	Size.	ohms.	Size.	ohms.
No. 1	.125	No. 11	1.25		
No. 4	.25	No. 14	2.5		
No. 7	.5	No. 17	5	No. 0000	.05
No. 10	1	No. 20	10	No. 0	.1
No. 13	2	No. 23	20	No. 3	.2
No. 16	4	No. 26	40	No. 6	.4
No. 19	8	No. 29	80	No. 9	.8
No. 22	16	No. 32	160	No. 12	1.6
No. 25	32	No. 35	320	No. 15	3.2

size and one half that of the next smaller size. There is, therefore, no difficulty in remembering this column. In the second division of the table the wires are ten sizes smaller than those in the first division; thus No. 11 corresponds to No. 1 and the resistance is ten

times as great. In the third division of the table the wires are ten sizes larger than those in the first division; thus No. 0 corresponds with No. 10 and the resistance is one-tenth as great.

From this table several new relations may be observed.

If the wire is one size smaller the resistance is 25 percent greater. For example: Compare No. 11 with No. 10, No. 12 with No. 11, No. 13 with No. 12, etc.

If the wire is two sizes smaller the resistance is 60 percent greater. For example: Compare No. 12 with No. 10, No. 16 with No. 14, No. 15 with No. 13.

If the wire is one size larger the resistance is 80 percent of that of the smaller wire. For example: Compare No. 9 with No. 10, No. 10 with No. 11.

If the wire is two sizes larger the resistance is 63 percent of that of the smaller wire. For example: Compare No. 11 with No. 13, No. 4 with No. 6.

From the foregoing the following are the ratios of resistance between wires of consecutive sizes.

.50, .63, .80, 1.00, 1.25, 1.60, 2.00.

WEIGHT—The weight of a wire is inversely proportional to its resistance. Therefore, the foregoing relations are the same for weight as for resistance, excepting that the weights increase as the size of the wire increases, instead of diminishing. The weights of successive sizes of wire, therefore, bear the following relation, beginning with the smaller wire:

.50, .63, .80, 1.00, 1.25, 1.60, 2.00.

If the weight of any size of wire is known, it is therefore seen that the weight of the next larger size is 25 percent greater, the weight of the second larger size is 60 percent and the weight of the third larger size is double; also, the weight of the sixth larger size will be four times as great, and the weight of the tenth larger size will be ten times as great.

The weight of 1 000 feet of No. 10 copper wire is 31.4 pounds. Therefore, the weight of No. 7 wire is 62.8 pounds; the weight of No. 0 wire is 314 pounds. The weight of No. 5 wire is 100 pounds per thousand feet, which is a convenient figure to remember. The weight of No. 2 wire is, therefore, 200 pounds, and the weight of No. 00 wire is 400 pounds.

AREA—The area of No. 10 wire is approximately 10 000 circular mils (more precisely 10 380). The area is proportional to

the weight. The area of No. 7 wire is, therefore, about 20 000 circular mils, of No. 0 wire 100 000 and of No. 0000 wire 200 000. The precise area of No. 10 wire is 10 380 circular mils. Taking this figure for easy calculation as 10 400 and following the process above indicated, the area of No. 0000 wire is found to be 208 000, which is very nearly 211 600, the figure in the wire table.

Diameter—The diameter of No. 10 wire is approximately 0.10 inch (more precisely 0.102 inch). The diameters follow the same ratio as the circular mils and weights except that this ratio applies to alternate sizes. Therefore the sixth smaller size has half the diameter and the twentieth smaller size has one-tenth the diameter. Therefore, as No. 10 is 0.10 inch, No. 16 is 0.05 inch and No. 30 is 0.01 inch; also No. 4 is 0.20 inch, and No. 000 is 0.40 inch; also No. 0 (two sizes smaller than No. 000) has 80 percent less diameter, or 0.32 inch. No. 00 lying between these sizes, may be presumed to be about 10 percent less than No. 000, or .36 inch; the diameter given in the wire table is 0.3648.

Reference to a complete wire table will show that the figures in the above examples and other figures which may be determined in the same way are correct within a few percent. A little practice in mental arithmetic will enable anyone to determine the approximate weight and resistance of wire of any size.

Summary—The things to be remembered regarding B. & S. gauge copper wire are the following:

A wire which is three sizes larger than another wire has half the resistance, twice the weight and twice the area. A wire which is ten sizes larger than another wire has one-tenth the resistance, ten times the weight and ten times the area.

No. 10 wire is 0.10 inch in diameter (more precisely 0.102); it has an area of 10 000 circular mils (more precisely 10 380); it has a resistance of 1 ohm per thousand feet at 20 degrees Centigrade, [68 degrees Fahrenheit,] and weighs 32 pounds (more precisely 31.4 pounds) per thousand feet.

The weight of one thousand feet of No. 5 wire is 100 pounds.

The relative values of resistance (for decreasing sizes) and of weight and area (for increasing sizes) for consecutive sizes are:

.50, .63, .80, 1.00, 1.25, 1.60, 2.00.

The relative values of the diameters of alternate sizes of wire are:

.50, .63, .80, 1.00, 1.25, 1.60, 2.00.

Circular Mils—Conductors of large size are usually specified

in circular mils. For example, 500 000 circular mils, 750 000 circular mils.

As No. 10 wire has approximately 10 000 circular mils and a resistance of 1 ohm per thousand feet and as the length of a wire which has a given resistance is proportional to its area, it follows therefore that the length in feet of a copper conductor having a resistance of 1 ohm may be found by dropping one cipher from the number expressing its circular mils, for example, No. 10 wire has 10 000 circular mils and a resistance of 1 ohm per 1 000 feet; a 300 000 circular mil conductor has a resistance of 1 ohm per 30 000 feet and a 1 000 000 circular mil conductor has a resistance of 1 ohm per 100 000 feet. The weight of a given length is proportional to the area; therefore, the weight of a conductor having 500 000 circular mils is greater than that of No. 10 wire in the same ratio that its area is greater. Five hundred thousand circular mils is fifty times that of No. 10 wire or approximately fifty times 32 lbs., which equals 1 600 lbs. per thousand feet. In this way the approximate characteristics of copper conductors of all sizes may be quickly ascertained.

To find resistance, drop one cypher from the number of circular mils; the result is the number of feet per ohm.

To find weight, drop four cyphers from the number of circular mils and multiply by the weight of No. 10 wire.

PROTECTIVE APPARATUS

THE EQUIVALENT SPARK GAP—A METHOD IN LIGHTNING ARRESTER DEVELOPMENT AND ITS APPLICATION TO THE PRODUCTION OF THE M. P. (MULTI-PATH) ARRESTER

By N. J. NEALL

To effect a comparative study of different kinds of protective apparatus some unit of measurement which can be adopted as a standard, is necessary. Quantative results can thus be obtained and investigation placed upon a scientific basis.

In the development of lightning arresters Mr. Alexander J. Wurts early appreciated the need of such a unit of comparison and for this purpose proposed that the freedom of discharge of an arrester should be measured by a definite form of air gap placed in multiple with the arrester and which would just fail to take the

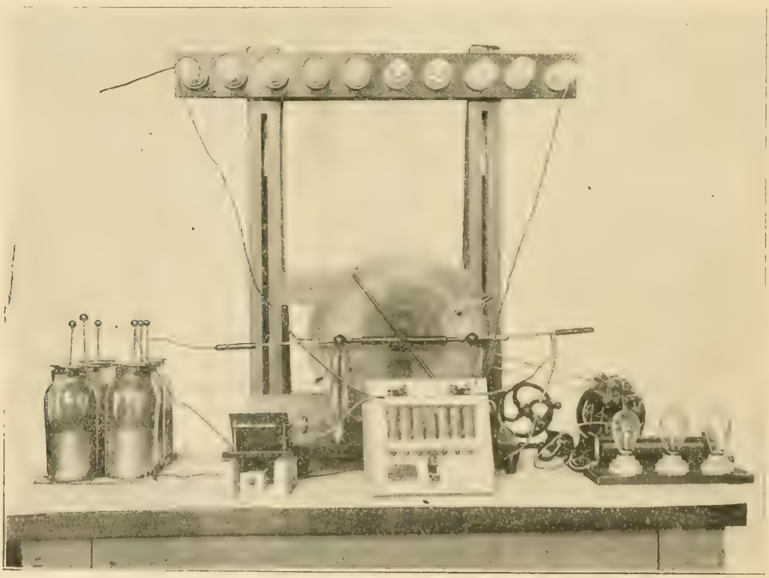


FIG. 1—A STATION TYPE NON-ARCING METAL LIGHTNING ARRESTER UNDER SERVICE TEST, AS MADE WITH A HOLTZ STATIC MACHINE

discharge. This opening, or gap, measured in inches, was called the equivalent spark gap.

The apparatus employed in this connection consisted of a Holtz static machine, which charged a battery of Leyden jars

placed across its terminals. The charges in the jars were then discharged over the gap and through the arrester under test. A measuring gap placed in multiple with this arrester gave the opening at which the discharge preferred to pass wholly over the arrester in preference to the air gap.

By attaching line leads to the terminals of the arrester, static discharges and line voltage could be simultaneously impressed on the arrester. Fig. 1 shows the equipment employed for such a test on a station type non-arcing-metal arrester.

Mr. Wurts made extensive use of this testing apparatus and was thereby enabled not only to produce arresters which would operate successfully in practice, but concerning which a definite estimate could be made in advance.

Some years ago, while studying improved methods for protecting apparatus against lightning, Mr. Percy H. Thomas found that the ordinary static machine was mechanically too weak for this purpose and he therefore designed and substituted the arrangement shown in Fig. 2.

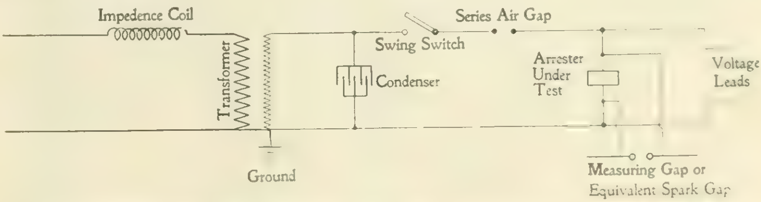


FIG. 2—CONNECTIONS FOR TESTING EMPLOYED IN THE EQUIVALENT SPARK GAP METHOD

A high tension transformer excited from the supply main through an impedance charges the condenser which can be intermittently discharged by the swing switch. The current which flows is pure electrostatic because the impedance coil acts in its well known way so to limit the flow of transformer short-circuit current at the interval of closing, that it becomes negligible. The air gap called the series gap is broken down by the condenser discharge which is thus thrown on the arrester or other object under test. In multiple with the arrester under test is placed a measuring gap called the equivalent spark gap. The other side of the circuit is grounded. This, it will be seen, is the same arrangement as that described above, but with stronger apparatus and of greater range and power. It thus enables quantitative measurements easily to be made which were before difficult.

STATIC DISCHARGES AND THE EQUIVALENT SPARK GAP

In order, however, to make the method clearer, procedure is as follows:

If a non-inductive resistance, such, for example, as a rod used for lightning arrester resistance, be connected in for test we shall find that the static discharge prefers to pump the measuring gap unless it is opened more than a certain amount. Fig. 3 shows a resistance rod measuring about four hundred ohms by Wheatstone bridge. The bright flash indicates that most, if not all, of the charge is jumping the air gap in preference to passing through the resistance. Fig. 4 shows the measuring gap

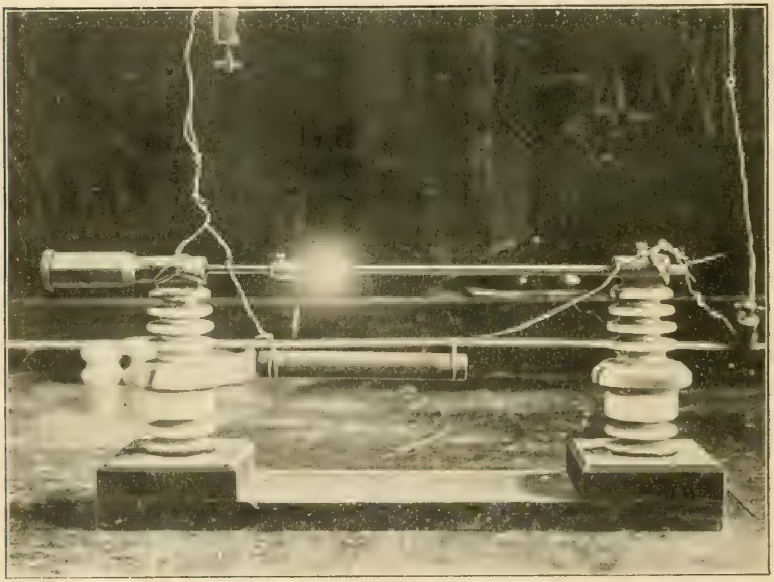


FIG. 3—A NON-INDUCTIVE RESISTANCE ROD BEING MEASURED FOR EQUIVALENT SPARK GAP. THE CHARGE HERE IS ALMOST WHOLLY PASSING OVER THE SPARK GAP

opened so far that the discharge must pass through the resistance rod. It does not do this easily, as is indicated by the streamers at both ends of the rod. If the gap were steadily reduced (in this case to .52 inches) we should reach a point where the static would just begin to fully leave the resistance rod path, and this would be considered the equivalent spark gap. Fig. 5 shows a small choke coil such as has been used for protection against lightning disturb-

ances, having a resistance of .036 ohms and an inductance of .0025 henries, or .095 ohms at 60 cycles, tested for equivalent spark gap which measures 1.25 inches. It is seen at once that the choke coil possesses the property of impeding the free passage of static discharges; which immediately establishes its value as a protective device on transmission circuits. A lightning arrester on the other hand should offer a very free path for discharge. Choke coils should have high equivalent spark gaps. Lightning arresters should have low. Both choke coils and lightning arresters are necessary to complete protection.

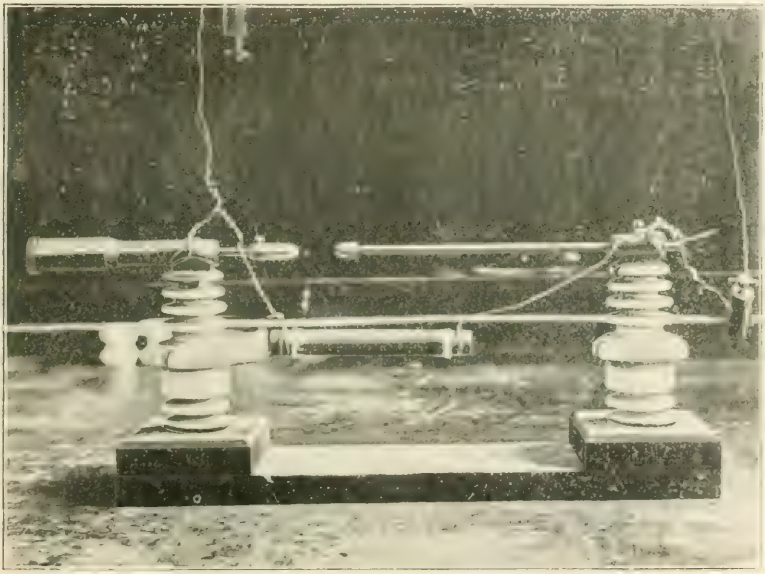


FIG. 2—A NON-INDUCTIVE RESISTANCE ROD BEING MEASURED FOR EQUIVALENT SPARK GAP. THE CHARGE IS HERE PASSING WHOLLY THROUGH THE RESISTANCE ROD

If a railway motor armature were piaced in the testing apparatus, as shown in Fig. 6, instead of the resistance rod, and a good lightning arrester placed in multiple with both the armature and the measuring gap, then, so long as the measuring gap were nearly closed, most of the static discharges would pass over it—as this is opened wider and wider, a point is reached where the arrester takes the discharge—if the arrester were disconnected and the masuring gap opened very wide so that all discharges must pass through the armature winding a puncture would soon occur. Owing

to the inductance of the armature winding this puncture would most probably occur near the point of entry of the static into the armature coil. In service such a condition as this could easily arise and a line current being present, the armature would be seriously damaged. A choke coil placed in series with the armature will, of course, greatly reduce the static strains.

THE M. P. LIGHTNING ARRESTER—It is of course clear that the best protection against rise of voltage to be devised for any apparatus will be that afforded by a simple air gap or its equivalent. Moreover, this air gap must be of such a size that the normal voltage impressed on the apparatus will not break it down—on the other hand it must offer a much freer discharge path to earth than is of-

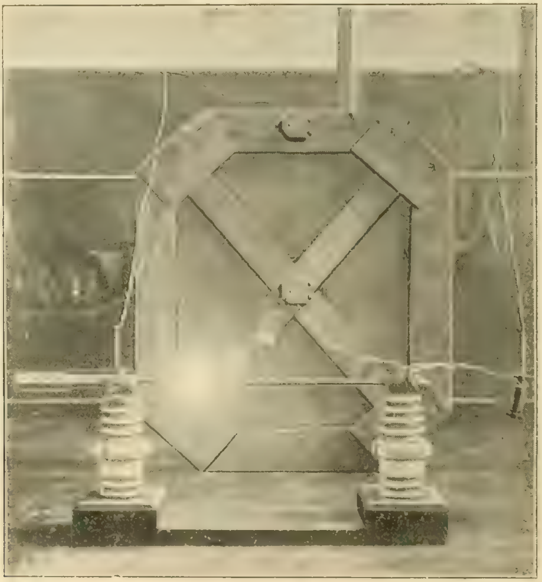


FIG. 5—A SMALL CHOKE COIL BEING TESTED FOR EQUIVALENT SPARK GAP

fered at any other point on the equipment, and it must not allow a short-circuit to be maintained by the current which follows the lightning discharge. With these simple conditions recognized, the real design of a protective apparatus begins; and with such a testing set, the development of any arrester to meet these conditions can be accurately and constantly carried forward.

The multi-path arrester was developed by Mr. Thomas with

such an equipment. This arrester, Fig. 7, consists essentially of small air gaps in series with a specially prepared block of carbon called the discharge block which may be conceived of possessing a great number of conducting particles suspended in an ordinarily no-conducting medium. With the advent of a static discharge there is no opposition to its passage but the generator current cannot follow. It is on this remarkable characteristic that the arrester

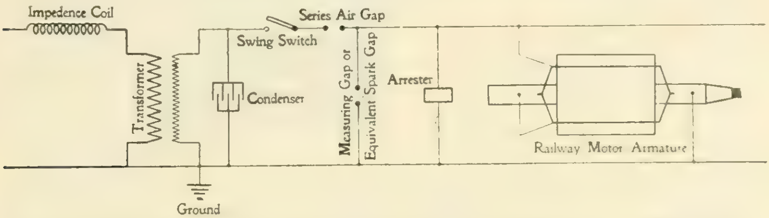


FIG. 6—CONNECTIONS FOR A TEST SHOWING THE DEGREE OF PROTECTION OFFERED TO A RAILWAY MOTOR BY A LIGHTNING ARRESTER

is founded. The discharge block is so shaped that the length of the path is short compared to the surface presented for discharge. The static spreads over the whole surface and divides itself into a great many separate paths from which the arrester has derived its name —multi-path—Figs. 8 and 9.

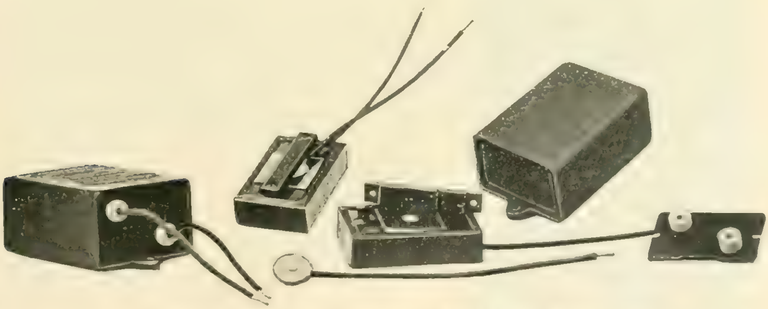


FIG. 7—THE M.P. (MULTI-PATH) LIGHTNING ARRESTER

The resistance of this block when measured by Wheatstone bridge may be many hundred megohms and yet its resistance to static discharge is extremely low. We thus see that the usual measurements of resistance and inductance do not give any idea of the resistance to static discharges, although for certain materials increased resistance or inductance is accompanied by increased equivalent spark gap.

The equivalent spark gap of the multi-path arrester com-

plete measures .07 to .10 inches while the best-known railway arresters range from .25 to .4 inches, respectively. Owing to the characteristic of the voltage curve corresponding to these openings of the gap, it follows that the M.P. arrester has even more than three to six times the freedom of discharge offered by the other arresters noted.

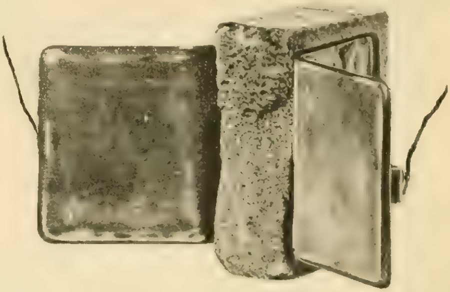


FIG. 8—AN M.P. ARRESTER DISCHARGE BLOCK PREPARED FOR SHOWING THE STATIC DISCHARGE

STATIC DISCHARGES WITH LINE VOLTAGE SIMULTANEOUSLY IMPRESSED ON THE ARRESTER — An arrester might easily have the lowest possible equivalent spark gap—and yet be unable to prevent the line current holding over after a discharge. By referring again to Fig. 2 it will be seen that it is possible to impress voltage on the arrester under test by connecting the leads for this purpose. With the passage of the static discharge over the arrester, we have an exact duplication of actual service conditions. The swing switch can be replaced by an automatic switch adjustable for any speed required.

FIG. 9 — STATIC DISCHARGE PASSING THROUGH THE DISCHARGE BLOCK ARRANGED AS SHOWN IN FIG. 8—FULL SIZE

Fig. 10 shows typical papers taken from the same air gap placed successively in series with different makes of resistance. The best service condition is given with the M. P. discharge block in series—which permits remarkably free discharge but no current to follow.

Under these circumstances the M. P. arrester reached its present form. It has been found equally good for either alternating or direct-current circuits which is another notable advance in arrester design.

TIME TESTS—Tests have shown this arrester to have an almost indefinite life. One, where for two and a half hours, rated line voltage being constantly on the arrester, static discharges were passed at frequent intervals until nearly 2 000 had been recorded. Even then the arrester was apparently good for many more.

EQUIPMENT FOR TEST—In general, the whole test outfit is quite simple. Only two pieces of apparatus require special mention.

First, the high tension condenser. Fig. 11 shows a standard high tension condenser removed from oil. This condenser consists of a number of sheets of fibrous material acting as the dielectric between metal plates mounted on fuller board supporting sheets.

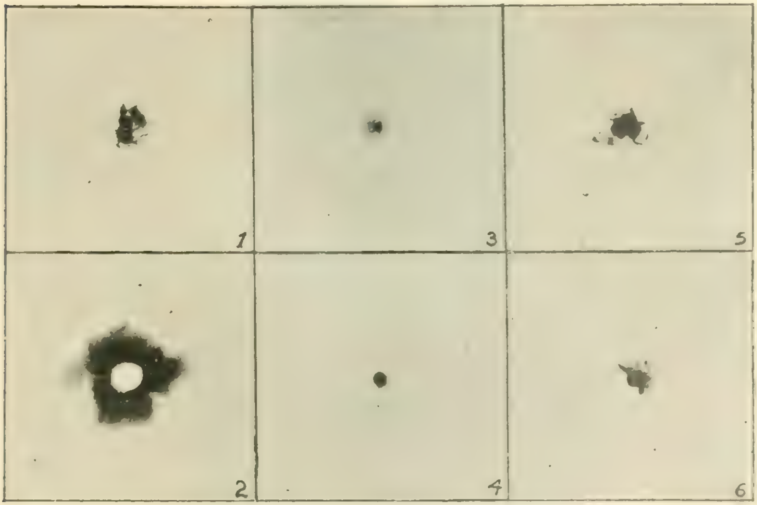


FIG. 10—PUNCTURED PAPERS SHOWING THE FREEDOM OF DISCHARGE OVER AN AIR GAP WITH AND WITHOUT LINE VOLTAGE OF 1 000 VOLTS

1. Simple air gap. Pure Static discharge
2. Same as No. 1, with line voltage added
3. Air gap with [illegible] ohms in series. Pure Static
4. Same as No. 3, with line voltage added
5. Air gap with M. P. Arrester in series. Pure Static discharge
6. Same as No. 5, with line voltage added

The condenser is well ventilated, solidly built and can be easily handled. For convenience in testing, special leads can be brought out from each plate. These condensers are in commercial use in static interrupters up to 55 000 volts and for testing are limited only by the space available, the size of material and the cost. A 100 000 volt testing set has been in frequent use. They will stand

severe wear and tear and render any tests of this kind absolutely reliable.

Second, the spark gap. The Electric Company has adopted as its standard a gap between bull-noses one-half inch in diameter made of non-arcing metal. This gap has been carefully calibrated for the voltages corresponding to given openings. The gap shown in the photographs is provided with a micrometer to facilitate in reading. Ordinarily 1/32 inch thread with a little adjusting to parts

FIG. 11—A HIGH-TENSION CONDENSER

of a turn, gives readings which are well within the acccuracy of the tests. For safety, the micrometer screw should be operated by a cord or some other insulating material.

Applicability of the Method—One of the most important points is that it is possible to check readings repeatedly. It should be noted that the connections of the testing set, altitude, etc., will affect the readings if taken at different places and connected with different

wires, etc., but given the apparatus once set up, then any number of tests can be made and the comparisons made are absolutely fair.

The method of the equivalent spark gap is suitable for high as well as for low-tension arrester testing. It is thus obvious, if we select such values of capacity, voltage, etc., for our testing set, as approximate those likely to affect an arrester during very severe normal lightning disturbances—especially with reference to the maximum length of line that will discharge itself over the arrester—we shall thereby be enabled to produce protective apparatus of such established strength that only the abnormal disturbances such as direct strokes, can in any wise adversely affect it.

ENGINEERING SHORTHAND

ABBREVIATIONS, SYMBOLS, PUNCTUATION, ETC., IN TECHNICAL PAPERS

BY GEORGE A. WARDLAW

DURING the last three years the writer has been chiefly occupied in reading copy for one of the large engineering societies of the United States. In the course of that time perhaps one hundred and twenty-five manuscripts on various engineering topics have been received and prepared for publication. It is rational to assume that these manuscripts were written by the authors, or, more likely, they were dictated to stenographers, and the type-written copy approved in substance and form before being submitted. With the authors, then, rests the responsibility for the engineering sanity and the literary form of these manuscripts, both in perspective and in detail. With the value of the engineering features described or the theory expounded, we are not now concerned; what concerns us particularly is the apparent tendency of writers on engineering topics to flout literary good use by approving manuscripts indiscriminately peppered with nondescript abbreviations of technical terms now in general use, abbreviations that sometimes puzzle the adept and always confuse the layman.

Technical terms themselves are abbreviations, for to the mind trained in engineering matters a technical term may express in a word or two the sometimes rather complex relations existing be-

tween cause and effect; it may connote the evolution of a complicated bit of machinery; it may be the briefest possible definition of a series of experiments. Power-factor, for instance, expresses in two short words a relationship that would ordinarily require about thirty-two words to define clearly. Why, then, should this abbreviation be further abbreviated to P. F.? And why should A. T. be allowed to masquerade as ampere-turn, while F. C. is denied the privilege of standing for field coil, S. W. for shunt wound and A. G. for air-gap? Clearly, the art of abbreviating is inscrutable; and clearly, too, it is in danger of being driven into the ground. Like other matters related to literary style, this art bears its part of the brunt of the conflict between good use and the principles of composition.

The question is then: Where shall we draw the line? What technical abbreviations shall we accept? What reject? Shall our accepting or rejecting them be determined by whim or fancy, or by reason, rational reasoning based on a compromise between what is right and what is expedient? From this point of view a close examination of most present-day engineering manuscripts will quite convince one that reason has been routed by whim, that the form in which a term may appear, will, to paraphrase the *Pickwick Papers* depend on the taste and fancy of the abbreviator. To the discerning man it is obvious that if this tendency to abbreviate is not checked, if the moths and rust of the technical literary world are allowed to consume all but the bare initial letters, we shall soon have the wordless story to describe the trussless bridge, the rimless wheel, the fluxless field, and perhaps the sleepless man.

A few engineering abbreviations have attained a dignified old age; their origin is lost in antiquity, but indubitably they were not conceived in iniquity and born in sin like some abbreviations of the present generation. With the time-honored abbreviations we have no quarrel—they are probably here to stay—but engineering interlopers like A. T. [ampere-turns], P. F. [power-factor], Swb. [switchboard], W. H. [Westinghouse], are barbarisms and must be expunged from all writing intended for publication. However frequently they may appear in manuscript, they should not be allowed to appear in type. In the words of the printer, "kill 'em!"

During the last three years the writer has made a note of the original and sometimes peculiar abbreviations in the manuscripts that have passed through his hands, and from time to time he has

transferred these abbreviations to a card index kept for that purpose. He now has a collection of perhaps four score of these cards, some of them containing half a dozen different forms of abbreviation of the same term. Horse power, for instance, and kilowatt, are sometimes arrayed in capitals, sometimes in small capitals, and sometimes in lower-case letters; and these initials are separated by periods, tied with hyphens, or coalesced—the form in which the abbreviation appears depending, as we have said before, on the taste and fancy of the abbreviator, or of his stenographer.

In this day of grace, as in other days, ridicule seems more convincing than argument. To ridicule, then, we turn as the most effective means of checking this tendency to coin abbreviations of technical terms. With the aid of our card index of engineering literary curiosities we shall compile a brief engineering article—an article that looks ridiculous in print, an article that sounds ridiculous when read aloud, and an article that will be understood only by dint of much effort. It is perhaps safe to say that it will not be understood at all, for nowadays the average technical man is too busy with really worth-while matters to puzzle his head over riddles. If the meaning of a bit of technical literature is not got at readily, the article will be passed along for something that promises a fair return for the amount of effort expended; if the style is vague or obscure, the article will not be read. Both vagueness and obscurity are likely to abound in an article studded with moth-eaten technical terms, terms in which only the bare initials are left to carry the dignity and meaning of the original word or words. The following article illustrates the writer's meaning; it also betokens what we may expect to see in print if the tendency to abbreviate technical terms is not curtailed.

In the P. H. there are five 1800 K. W., 3 φ, 25 C., 11 500 V turbo-generators. The Avg. KW. output is 7 500; the Ave. K. V. A. output is 8200; the P. F. is 91. The turbines are of W. H.—Parsons[1] make, running at 750 R. P. M. The steam consumption is 14.2 lbs. per B. H. P. H.

The lighting circuits are operated by a 3-cyl., 15 h. p. W. H.[2] gas-engine direct connected to a 10 kw., 2 Ph., 60 cy. 550 v. A-C-B[3] generator. The av. gas consumption per K. W. H. is 35 Cub. ft. Assuming an Avg. calorific value of 625 B. T. U. per foot for coal gas, the heat consumption is 24 000 B. t. u. per K. W. H., 18 200 btu per E. H. P. H., and 14 500 b. t. u. per B. H. P. The av. cost of gas charged to the engine is 33c./ M. Cub. Ft.

The transformers are of A. E. G.[4] type, 3-$\varphi\nabla$ connected. At the substations the voltage is stepped down to 390 v. and changed from 2 Ph. to 3 φ by suitable connections.

The P. D. at the motor brushes is indicated by the A. C. V. M. on the A. C. S. B. in the P. H. to be 115 vlts. The A. C. A. M. at 10 A.M. on the A. C. S. B. indicated 400 amps. The W. M. on the Swb. indicated 44 Kw.; in this case the p. fac.[5] was approximately unity.

Car No. 159 was equipped with four No. 49 W. H. motors; No. 160 with four 70 H. P. G. E. motors. In each case the Av. S. S. M. P. H.[6] was 38.9 and the energy consumed per K. W. H. P. C. M.[7] was 2.3. The Max. accel. was 0.25 M. P. H. P. S.[8] The R. M. S.[9] av. value for one day's run was 43.6 Amps.

So much for the disorder and its consequences. Now for the remedy. The tendency of engineer authors to adopt this kind of engineering shorthand became so apparent that early in January, 1904, the writer thought it advisable to call it to the attention of The Editing Committee of the AMERICAN INSTITUTE OF ELECTIC ENGINEERS. The chairman of that committee then invited the secretaries and editing committees of the four national engineering societies to coöperate in the endeavor to develop a rational system for abbreviating technical terms. A series of conferences was held and the practices of the editing committees and proof-readers of the several societies were compared, and adjusted to meet existing conditions. After mature deliberation the committee adopted the following set of rules based on broadly general principles, making due provision for exceptions whenever expediency should demand that a rule be not rigidly adhered to. The full report of this Committee is appended. It illustrates in a general way the typographical practice now followed by the four national engineering societies, a practice that will, let us hope, eventually change and chasten the taste and fancy of the abbreviators.

REPORT OF A COMMITTEE TO COÖPERATE IN STANDARDIZING ABBREVIATIONS, SYMBOLS, PUNCTUATION, ETC., IN TECHNICAL PAPERS.

This Committee is the result of a desire of the authorities in charge of the publications of the four national engineering societies to coöperate in this matter.

The members of the Committee are the following:

CHARLES WARREN HUNT, *Secretary*, American Society of Civil Engineers.

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1. Westinghouse-Parsons.
2. Westinghouse Gas-Engine.
4. Actien Elektricitäts Gesellschaft.
5. Power-factor.
6. Schedule speed miles per hour.
7. Kilowatt-hours per car mile.
8. Miles per hour per second.
9. Square root of mean square.

D. S. Jacobus, *Vice President,* American Society of Mechanical Engineers.
Joseph Struthers, *Assistant Editor,* American Institute of Mining Engineers.
Cary T. Hutchinson, *Chairman, The Editing Committee,* American Institute of Electrical Engineers.

This Committee has held several meetings; it seemed advisable, at the outset, to limit its discussions closely to the general subject of abbreviations. Further, it seemed best to formulate a few general rules to be followed in making abbreviations, rather than to compile a list of forms to be recommended.

The Committee decided to limit the subject more narrowly by considering only abbreviations to be used in the text, or general reading matter, and not those to be used in special matter, such as columns, box-headings, plates, figures, etc. The rules that follow are intended to apply to the text, and not primarily to such special matter. This Committee is of the opinion that it is impracticable to make general rules applicable to special matter; it believes that the rules herein stated should be followed as far as possible, even in special matter, realizing, however, that clearness is of the first importance, and that all rules must be secondary to that consideration.

Referring, then, to abbreviations in the text or general reading matter, the Committee recommends the observance of the following rules:

1. Use abbreviations only after nouns denoting a definite quantity. Example: "The power plant has a capacity of 10 h.p." not "10 horse power"; but "The capacity of the plant, in horse power, is ten."

2. Do not abbreviate abstract or descriptive words. Example: "Horizontal return tubular boilers" not "h.r.t. boilers."

3. Use lower case characters for abbreviations. An exception to this rule may be made in the case of words spelled normally with a capital. Example: "B.t.u." and not "b.t.u." nor "B. T. U." (British thermal unit). "U. S. gal." (United States gallon). "B. & S. gauge" (Brown & Sharpe gauge).

4. Use a period after each abbreviation. In a compound abbreviation do not use a space after the period. Example: "i.h.p." and not "i. h. p." (indicated horse power).

4. Use a hyphen to connect abbreviations in cases where the words would take a hyphen if written out in full. When a hyphen is used, omit the period immediately preceding the hyphen. Example: "3 kw-hr." and not "3 kw.-hr." (3 kilowatt-hours).

6. Use all abbreviations in the singular. Example: "17 lb." and not "17 lbs." (17 pounds). "14 in." not "14 ins." (14 inches).

7. Never use "p." for "per" but spell out the word. Example: "100 ft-lb. per ton" (100 foot pounds per ton); "60 miles per hr." (60 miles per hour).

8. Use decimals, as far as possible, in place of vulgar fractions. Example: "1.25 ft." not "1¼ ft."

9. In general, spell out an adjective qualifying the name of a unit. Example: "Boiler h.p." (boiler horse power). The exceptions to this rule are: "i.h.p." (indicated horse power), "e.h.p." (electric horse power), "b.h.p." (brake horse power), "e.m.f." (electromotive force), "m.m.f." (magnetomotive force).

10. Use "Fig." not "Figure." Example: "Fig. 3" and not "Figure 3."

11. In all decimal numbers having no units a cipher should be placed before the decimal point. Example: "0.32 lb." not ".32 lb."

12. In the notation of large numbers, use "en" spaces instead of commas. Example: "1 520 125" not "1,520,125."

13. Use the word "by" instead of "x" in giving dimensions. Example: "8 by 12 in." not "8x12 in."

14. Never use the characters (′) or (″) to indicate either feet and inches, or minutes and seconds as periods of time.

The following forms are given as illustrations of these rules and are recommended to be used. Terms that are sometimes abbreviated but should be spelled out are noted without corresponding abbreviations.

Name.	*Abbreviation.*
Amperes	
Ampere turns	
Brake horse power	b.h.p.
British thermal units	B.t.u.
Candle-power	c-p.
Centigrade	cent.
Centimetres	cm.
Circular mils	cir. mils
Cubic	cu.
Diameter	
Electric horse power	e.h.p.
Electromotive force	e.m.f.
Fahrenheit	fahr.
Feet	ft.
Foot-pound	ft-lb.
Gallons	gal.
Grains	gr.
Grammes	g.
Gramme-calories	g-cal.
High pressure cylinder	
Hours	hr.
Inches	in.
Indicated horse power	i.h.p.
Kilogrammes	kg.
Kilogramme-metres	kg-m.
Kilogramme-calories	kg-cal.
Kilometres	km.
Kilowatts	kw.
Kilowatt-hours	kw-hr.
Linear	lin.
Magnetomotive force	m.m.f.
Mean effective pressure	
Miles	
Miles per hour per second	miles per hr. per sec.
Millimetres	mm.
Milligrammes	mg.
Minutes	min.
Metres	m.
Metre-kilogrammes	m-kg.
Ohms	
Per	
Percentage	% or per cent.
Pounds	lb.
Power-factor	
Revolutions per minute	rev. per min.
Seconds	sec.
Square	sq.
Tons	
Volts	
Watts	
Watt-hours	watt-hr.
Watts per candle-power	watts per c-p.
Yards	yd.

ONE SIDE OF CONSTRUCTION WORK

BY W. H. RUMPP

THE work of the construction department of the Electric Company may be divided into three general classes:

First, contract work, which is all the work agreed upon in consideration of the original price and includes the delivery and erection of the apparatus ready for operation, or the services of an engineer to superintend the erection, the purchaser furnishing all the labor. In this case the charge is predetermined and a general order issued previous to the commencement of the work and it is then the aim of the department to install the apparatus in the best possible manner.

Second, the work which is to be charged to the customer direct and in addition to the contract price of the machinery. In this case as in the foregoing the charge is predetermined and is something with which the engineer has nothing to do. It is then the aim of the department to proceed with the installation with all the speed compatible with good workmanship and give the customer the best possible service, keeping in mind that each day and its expenses will be charged to the local company and that it is immaterial to the Electric Company upon what work the engineer is engaged so long as the customer is satisfied. This class of work is usually called for by companies who having bought apparatus believing they can install it themselves afterward change their minds; or by large general contractors who purchase all machinery and have the various builders install it. As a rule this class of work is the cause of much correspondence and some controversy when the invoice covering the time and expense of the engineer is presented and it therefore behooves the man on such work to keep a strict account of his time and to be accurate in his reports to the office.

Third, a class termed investigation and repair work, which is a kind of work not generally sought after by engineers. It is not to be presumed that men slight this class of work, but owing to their frequent failure to get the desired result without much cutting and trying and owing also to the dissatisfied mood in which the customer usually is, men do not seek out this class of work, but prefer

jobs where the results are more certain and the conditions more pleasant.

Nevertheless, this work must possess a certain charm to the engineer, who, by the exercise of great patience and vigilance is able successfully to overcome defects which elude ordinary observation though all the while they loudly proclaim their existence.

One point, which is sometimes lost sight of by new men in construction work, is the fact that local electrical companies and other business corporations, often have electrical men in their employ who know a thing or two notwithstanding that they have not had the benefit of a technical education, and it is therefore unwise to jump at any conclusion before making a thorough investigation. The local company's engineer or electrician will invariably endeavor to overcome the difficulty himself before calling in outside help and after having done so, it cannot be but gratifying to him to see an expert from the factory puzzled about the nature of the trouble. We engineers of the construction department have without doubt the advantage of a wider experience and perhaps a more intimate knowledge of the structure of the apparatus, but it is very humiliating to feel sure that you have the trouble located, make a test and fail and then have the local company tell you that their man tried the same trick hours before you arrived. I would therefore again impress upon you the advantage of making a thorough investigation and letting the local company believe that you know that they know a thing or two; and it is my opinion, obtained of experience, that your burden will be lightened considerably by information and help which could not be gained otherwise.

Investigation and repair work may be divided into two sections: mechanical and electrical. In the former cases the causes and remedies are both usually apparent and we are called upon because of our knowledge of the structure of the apparatus and because we are in better position to supply the necessary parts than outside firms. Electrical troubles are usually not so apparent and we are called upon not only to repair the defect, but to diagnose the case and determine the real trouble.

The repair work always calls for very prompt action and good workmanship, and a proper appreciation of certain clerical regulations, by the engineer, means a great saving of time to both the customer and ourselves. The necessity for complete information sometimes does not appeal to the engineer because he usually has

a conversation with the salesman and becomes acquainted with the facts, but this extra information is denied the department at Pittsburg which can only read as it runs. I have a case in mind which occurred last week when we received an order which had been completed by a district engineer and which called for the hanging of two arc lamps in a certain office. Opposite the item of charges on the order were the letters W. E. & M. Co., and the order and green sheet covering time and expense were sent in without a report or comment of any nature whatsoever. After some correspondence, we were enlightened that the arc lamps had been hung for display purposes and that the charges were to be made against that particular sales office. Now this information while of no especial value to the engineer was absolutely necessary for our auditing department in order that the charge might be placed in the proper column.

Another case in point which occurred recently is that of an engineer who sent in a district office order requesting that we send him a number of coils for a certain motor. He gave the size, speed and alternations of the motor, but failed to mention the serial number. This, perhaps, seemed to him an unimportant item, but it so happens that we have made three different styles of these motors all of the same horse-power, speed and alternations, on three different electrical specifications, and each one of these different styles had some change in the coils. This fact, while not appreciated by the engineer, made it impossible for us to send him the necessary repair parts of this particular motor until he had advised us the serial number. These delays, as you will understand, do not tend to pacify the customer who has probably experienced considerable delay already owing to the non-use of his apparatus. Only last week we received a request for a great number of parts and the services of an armature winder to repair some 200 kw rotary converters. The engineer, of course, was familiar with the situation, but did not recognize the fact that this department handles at least twenty-five times as many orders as he does, and it was therefore necessary that we go over our records showing the converters which had been purchased by the customer and even then it was a streak of luck that we discovered that all of these converters are of the same size and of the same characteristics. The fact that we were enabled to give prompt attention to the customer was not in any way due

to the carefulness of the engineer, but simply to good fortune which cannot be at all depended on in investigation and repair work.

Within the last two weeks one of our oldest engineers who is a very capable man technically, wrote us a letter in which he desired us to ship him five 5-candle power synchronizing lamps, Edison base. He failed to mention any voltage and we were therefore compelled to either choose between sending him the usual 110-volt lamp or consult the records which would give us the stock order of his switchboard, take out this stock order, and go over it until we discovered the number of the blue print which would show the front view of the switchboard. We would then have to get out this blue print and go over it in order to see what voltage had been specified. If any of you have experienced the unavoidable delay in getting stock orders and office copies of blue prints you will realize that this latter method would have precluded our shipping the lamps the same night inasmuch as we did not receive the engineer's request until the afternoon's mail. We, therefore, took the chance and shipped 110-volt lamps. In addition to the foregoing, it seems reasonable to believe that the engineer could have purchased the necessary lamps at the destination because he was working in a city of considerable size and one which is a mercantile center for a large area of country. This point evidently slipped the man's mind entirely and we have no assurance that an effort was made by him in this instance to save his department trouble.

Another instance of trouble with rotary converters which was presumed by the local company to be purely electrical and which we also presumed to be electrical, finally turned out to be one of a mechanical nature, but it took the services of two different engineers at two different times to bring the trouble to light. The first engineer made an investigation and suggested certain changes in the customer's line, thereby keeping up the voltage at the sub-station in which the bothersome rotaries were located. The changes apparently benefited the operation to a greater or less degree and our man feeling confident that a few more minor changes would overcome all trouble, left the local company feeling sure that in the future the ordinary attention would be entirely sufficient for continued successful operation. However, within a month we were again requested to investigate the same old trouble with the customer's rotaries. Another engineer was dispatched who expressed his determination before leaving of either making the apparatus right or eating it, and we presume this latter determination caused him to

search very diligently for the difficulty. The main trouble seemed to be that although the armatures of the rotaries were in perfect balance, when a heavy load came on them, they nearly shook the station down. The second engineer after a thoughtful study and careful questioning of the operator made a careful examination of the floor upon which the rotaries rested. In this case the machines were on the second floor of the sub-station and our man discovered that their main weight was being supported by a beam which went directly beneath the center of the fields. It was then found that the floor had settled slightly on each side of this support, and while running light the machines would be apparently steady, but when loaded they would vibrate rapidly from one side to the other, the number of vibrations increasing in direct proportion with the time the heavy load stayed on. The whole trouble was finally eliminated by introducing supports made of six by six timbers placed on end between the corners of the bed plates and the solid foundation of the first floor.

During December, 1904, the department was called upon to investigate trouble with quadruple equipments consisting of No. 56 motors and their accompanying apparatus, which were giving some trouble on a street railway in the west. The local company reported that they were having difficulty with the armatures of the No. 1 and No. 3 motors of their equipments getting down on the poles, due to the rapid wearing of the bearings. They also stated that these motors got considerably hotter than the No. 2 and No. 4 motors, and that the No. 3 motor was always the hottest motor on the car. At the time of this report the customer had three cars laid up, and although his information would in no way help the engineer, our man did the only possible thing under the circumstances and dispatched an armature winder to destination with instructions to get some of the company's cars running by repairing the burnouts. This was done, of course, without regard to the cause of the trouble, merely to keep the customer's road from being tied up altogether. The engineer proceeded to the seat of war at his earliest opportunity and made an investigation which brought forth the following data:

The road was opened about the 1st of August, 1904, and all the cars were placed in service about that time, and no trouble was experienced until November 28th, when car No. 104 was brought into the barn with the armature of its No. 3 motor down. Eight con-

mutator leads were burned off from contact with the copper dampers on the field coils. The bearing on the pinion end had burned out, and after re-babbitting it an armature furnished by another firm was placed in the No. 3 motor and the car was run 1 200 miles or about four days. Following this the car stood in the barn two days and was then taken out, and after running forty miles the No. 3 motor was reported warm. Our man was unable to learn whether the entire motor was warm or simply the bearings, but at any rate after making six more miles the No. 1 and No. 3 motors were cut out and the car run 16 miles to the barn. An inspection then showed that the armature of the No. 3 motor was down on the pinion end, and that three bands were off that end. This trouble induced the local company to make a thorough inspection of all their motors and the result was that the bearings on the pinion end of all of the number three motors were shown to be down so that the armatures were just ready to drag on the pole tips. The armatures of the No. 1 motors were also down, but not so bad as the No. 3 motors. This difficulty had never been looked for until the local company lost the first armature and then, of course, their other cars showed the same trouble in a very short time, and it was finally necessary to operate several cars on the No. 2 and No. 4 motors alone as no spare armatures were at hand. Our engineer was of the opinion that perhaps the tilting of the trucks in starting and stopping caused the wheels, which were attached to the armatures of the No. 1 and No. 3 motors, to skid and thereby increased the weight on the bearings, burning them out rapidly. This opinion was reversed by the engineering department, which, after going over our reports and their records, decided that the motors were being worked very hard and that the trouble was caused by imperfect lubrication of the bearings. It was also shown that a slightly inferior quality of babbit had been used in the repaired bearings and the customer was asked to use only the best metal, make a closer inspection of his cars, not to overcrowd the acceleration and to give particular attention to the lubrication of the bearings. That the neglect of these points was the cause of the trouble would seem evident inasmuch as we have not heard from them since our armature winder left after repairing the windings on the damaged armatures.

Under the heading of electrical trouble, I would bring to your attention a very peculiar case which one of our district engineers was called upon to investigate. A certain street railway had a car

equipped with two No. 56 motors and one K-11 controller, and the equipment had repeatedly caused trouble by refusing to go forward after a stop had been made, and in spite of all the motorman could do, it would then be necessary to back the car into the barn. One night during December after a day during which the car had operated in good shape, it was placed in the barn in apparently first-class condition. In the morning the attendants were unable to run it out as the car refused to go in any but a backward direction. We were then notified, and only half an hour before the arrival of our man, the local company made an attempt to get the car out without success. Upon our engineer's arrival, he personally tried the equipment and brought it out of the barn without any difficulty. The car was then operated over the line without showing the least evidence of trouble, and as our engineer was not a spiritualist, he decided to make a searching investigation of the controller connections, inasmuch as the customer had a very complete list showing the various phases of the car's disease. The investigation failed to disclose any vital discrepancies and the only conclusion which we were able to reach was that the fingers of the reverse drum did not always make contact when the drum was in the forward position, but did make contact when the drum was in the reverse position. This opinion was not verified by any marks of burning or bad contact on the fingers or plates, but the engineer advised the local company to look for trouble at these particular points when the car again balked, and as we have not heard from the customer since, we have every reason to believe that we discovered the difficulty.

Another very peculiar case of electrical trouble caused by the extraordinary ignorance of the electrical attendant occurred in Pittsburgh within the last two years, when a customer's operator dismantled the brush holder to clean it, and after replacing it found that his apparatus would not work. He thereupon called on the company for the services of an expert to whom he stated that he had dismantled the brush holder, cleaned it and re-assembled it in exactly the same manner that it had been previously assembled, but that when he started up the generator, which was one of the regular multi-polar type, he was unable to get any voltage. He then separately excited the fields from another generator and claimed that the brushes on the machine to which he had given attention became white hot and smoke came out of the armature. Our man procured a light and inspected the brush holder, whereupon he found that

the customer's operator in re-assembling the brush holder, had gone to considerable trouble in order that he might put the cross connections between the brushes which are 90 degrees apart and which, of course, are the positive and negative brushes. Notwithstanding the fact that the cross connections had to be bent in order to be inserted in this manner, the attendant still claimed that this was the way in which they were on before he touched the apparatus. When exciting from a separate source, he, of course, had a dead short circuit on the armature, and it was only owing to the first-class design of the machine that he did not do considerable damage.

A great many minor troubles are experienced by the district engineers in the large districts, most of which are caused by either inattention or the lack of proper attention and, as a rule, these difficulties are easily overcome and the question of who shall pay our time and expense is one which is not hard to decide. These troubles consist chiefly of brushes not being down on the commutator, burned out bearings, fuses out of the line, or some other difficulty which is at once evident, and is no trouble to overcome.

A very peculiar case appeared in Chicago not very long ago, in which the customer, a large furniture company, purchased a motor from us direct and installed it themselves. They were alarmed at the excessive heating of the bearings when they first started to operate it, and asked that a man be sent them to go over their work. Much to their chagrin, our engineer discovered that they had filled the oil wells of the bearings with furniture polish instead of with oil. Their trouble was readily overcome by a thorough cleaning of the bearings and wells and the introduction of a good light oil.

Of late considerable instrument trouble has been handled by this department, but in almost every instance this work has been taken care of by a specially instructed man detailed for this work. It has nevertheless been a source of considerable anxiety for us to procure full and comprehensive reports of the repairs made to the individual instruments, as this information does not seem to appeal to the repair man, but you will understand that this information is very necessary in order that we may overcome these difficulties in the future manufacture of apparatus.

Before closing these remarks I again desire to impress upon you the great importance of making your reports very accurate on all work and giving all details as known by you, not leaving

it to the imagination of the men in the office to guess at what particular point in the circuit you took your readings or made your investigations, and never suppose that the men in the office are as familiar with the particular job as you are. Also remember that while, as a rule, an engineer is on but one job in a day, this office is handling several hundred times as many open orders, a great percentage of which require daily attention, and it is therefore necessary that for prompt results you give the office the detailed information and accompany the same by serial numbers and a description of the apparatus in trouble; this will enable us to make a ready identification of it at the factory.

FACTORY TESTING OF ELECTRICAL MACHINERY—XV

BY R. E. WORKMAN

ROTARY CONVERTERS—CONTINUED—

Short-Circuit on Direct-Current Side—A test usually made is a direct-current short-circuit test, which is little more than a test of the commutation, as the field is necessarily very weak.

Preparations for Test—The machine is run just as in the iron-loss test by means of a driving motor, belted to the secondary of the starting motor, the frame of which is temporarily removed. The direct-current leads are short-circuited through an ammeter.

Conduct of Test—The machine is run up to speed and then a very small current put through its shunt windings from a separate source of excitation. This field current is raised till the armature current reaches its full-load value, the brushes being given a suitable forward lead, as the machine is running as a generator. Under these conditions, i. e., with a very weak field, the test of commutating power will be very severe, but practically all the heating that takes place will be that due to the copper losses in the armature and field.

The parts whose temperatures are to be measured are the armature copper, the armature iron and the commutator.

MINIMUM ARMATURE CURRENT—This test is made as described for synchronous motors on page 117 of THE JOURNAL for February, 1905.

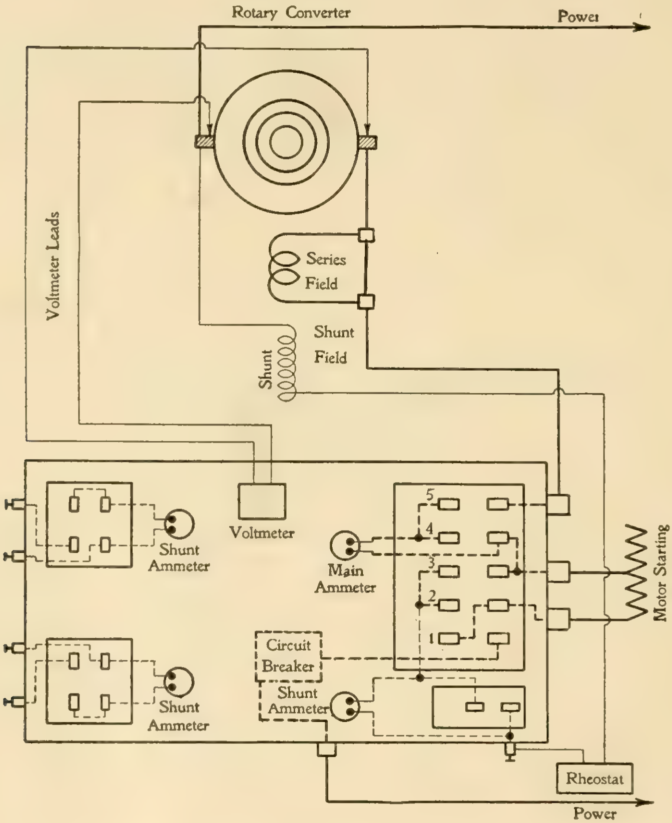


FIG. 70—CONNECTIONS FOR TAKING THE IRON LOSS CURVE ON A ROTARY CONVERTER RUNNING IT AS A SHUNT MOTOR

COMPOUNDING—This test is quite analogous to the regulation test made on a direct-current generator, giving the relation between the output in kilowatts and the direct-current terminal volts.

Since there is always a fixed ratio between the alternating-current voltage and the direct-current voltage, the direct-current voltage can be raised or lowered only by raising or lowering the alternating-current voltage. The compound winding on the fields of

a converter serves to strengthen the field flux as the load comes on, but strengthening the field of a rotary converter as a synchronous motor only changes the phase relation, producing a leading current with respect to the line voltage, and does not directly increase either the alternating or the direct-current voltage.*

The alternating-current voltage impressed on the converter terminals may be altered by placing inductance in the circuit between the generator and the motor. This inductance produces an e.m.f. of self-induction 90 degrees behind the current and therefore 90 degrees behind the generator e.m.f. when the current is in phase with the generator e.m.f. The e.m.f. impressed on the converter then is the geometrical sum of the e.m.f. of two sources connected in series, viz., the generator and the inductance of the line. Whether this e.m.f. of self-induction adds or subtracts will depend entirely upon the phase relation of the current with respect to the generator voltage, which in turn is altered by the effect of the series turns at the converter.

In making a compounding test, it is therefore necessary to provide the circuit with inductance. This may sometimes be obtained to a sufficient degree in the transformers, if not, it will be necessary to provide impedance coils in the line.

A further compounding will be obtained if the generator field current be held constant instead of the generator voltage, since the effect of a leading armature current is to increase the effective generator field excitation, so that if the generator field current is held constant, the generator voltage itself will increase as the load comes on. This is the condition that obtains in practice and it is therefore generally the best method to follow in testing.

Commercial Tests

The tests are:

(1) Polarity.

(2) Synchronizing with starting motor.

(3) Temperature. Check on the armature windings.

(4) Insulation.

(1) Polarity—This test is made exactly as in the case of

*See Voltage Regulation of Rotary Converters in the Journal for March, 1904.

Minimum Armature Current—This test is made as described for synchronous motors on page 117 of The Journal for February, 1905.

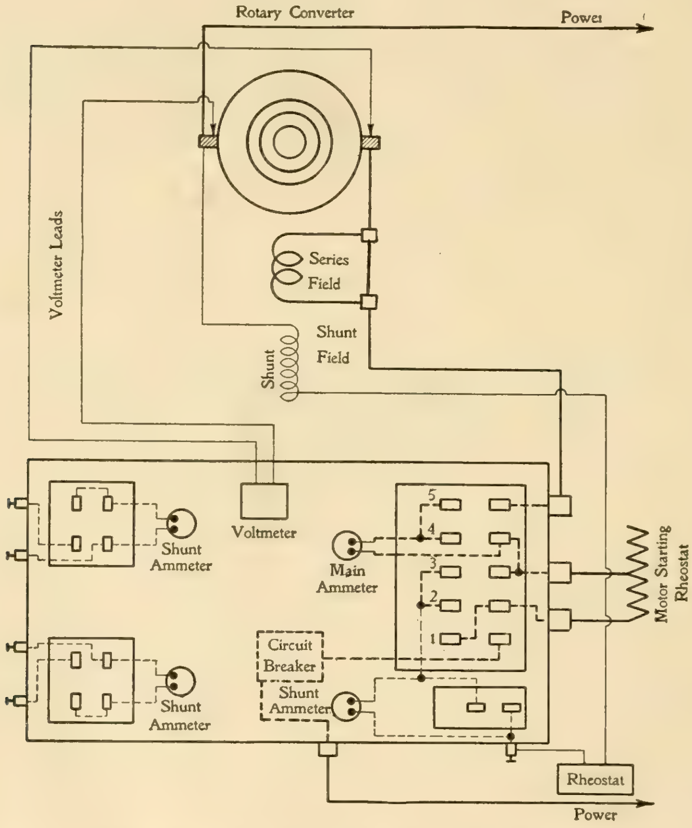


FIG. 70—CONNECTIONS FOR TAKING THE IRON LOSS CURVE ON A ROTARY CONVERTER RUNNING IT AS A SHUNT MOTOR

Compounding—This test is quite analogous to the regulation test made on a direct-current generator, giving the relation between the output in kilowatts and the direct-current terminal volts.

Since there is always a fixed ratio between the alternating-current voltage and the direct-current voltage, the direct-current voltage can be raised or lowered only by raising or lowering the alternating-current voltage. The compound winding on the fields of

a converter serves to strengthen the field flux as the load comes on, but strengthening the field of a rotary converter as a synchronous motor only changes the phase relation, producing a leading current with respect to the line voltage, and does not directly increase either the alternating or the direct-current voltage.*

The alternating-current voltage impressed on the converter terminals may be altered by placing inductance in the circuit between the generator and the motor. This inductance produces an e.m.f. of self-induction 90 degrees behind the current and therefore 90 degrees behind the generator e.m.f. when the current is in phase with the generator e.m.f. The e.m.f. impressed on the converter then is the geometrical sum of the e.m.f. of two sources connected in series, viz., the generator and the inductance of the line. Whether this e.m.f. of self-induction adds or subtracts will depend entirely upon the phase relation of the current with respect to the generator voltage, which in turn is altered by the effect of the series turns at the converter.

In making a compounding test, it is therefore necessary to provide the circuit with inductance. This may sometimes be obtained to a sufficient degree in the transformers, if not, it will be necessary to provide impedance coils in the line.

A further compounding will be obtained if the generator field current be held constant instead of the generator voltage, since the effect of a leading armature current is to increase the effective generator field excitation, so that if the generator field current is held constant, the generator voltage itself will increase as the load comes on. This is the condition that obtains in practice and it is therefore generally the best method to follow in testing.

Commercial Tests

The tests are:

(1) Polarity.
(2) Synchronizing with starting motor.
(3) Temperature. Check on the armature windings.
(4) Insulation.

(1) Polarity—This test is made exactly as in the case of

*See Voltage Regulation of Rotary Converters in the Journal for March, 1904.

a direct-current or alternating-current generator or motor, as described in THE JOURNAL for October, 1904, page 542.

(2) SYNCHRONIZING TEST—This test is made as described under experimental testing.

(3) TEMPERATURE TEST—This is generally taken on direct-current short-circuit as described under experimental tests. The check on the armature windings is taken during this test by measuring the voltage of each phase. If these results do not show the e.m.f. generated in each phase to be the same, there must be some mistake in the winding.

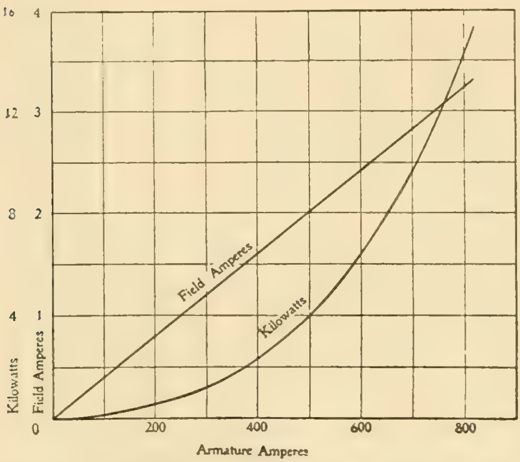


FIG. 71—SHORT-CIRCUIT CURVES OF A 250-KW, THREE-PHASE, 500-VOLT, 25-CYCLE ROTARY CONVERTER

(4) INSULATION—This is taken just as described for direct-current machinery.

Where large rotary converters are tested, whether they are standard machines or not, a complete set of experimental tests is made.

(3) SHORT-CIRCUIT READINGS ON THE ALTERNATING-CURRENT SIDE—These are taken exactly as in the case of an alternator. Such a curve from the test of the converter cited in Part XIV, March, 1905, is given in Fig. 71.

(4) SYNCHRONIZING—This test is made to find whether the converter will synchronize with the line when started by means of its starting motor. The starting motor is built with fewer poles than the converter and consequently has a higher synchronous speed. The starting motor is then designed so that with the load imposed by the iron-loss and friction of the converter excited to normal voltage, its speed shall be the synchronous speed of the converter.

Preparation for Test—The test table used is that shown in Fig. 72. It is simply an iron-loss table with some additional switch-

ing apparatus. The connections for the case of a three-phase machine are shown in the figure. One terminal of the starting motor is connected direct to the line or to the transformers, while the other two are taken through the table. The voltage on the terminals of the motor is generally regulated by means of taps in the secondaries of the transformers used; a transformation from two-phase to three-phase being sometimes required. In order to be able to tell when synchronism is reached, a series of lamps is connected between the

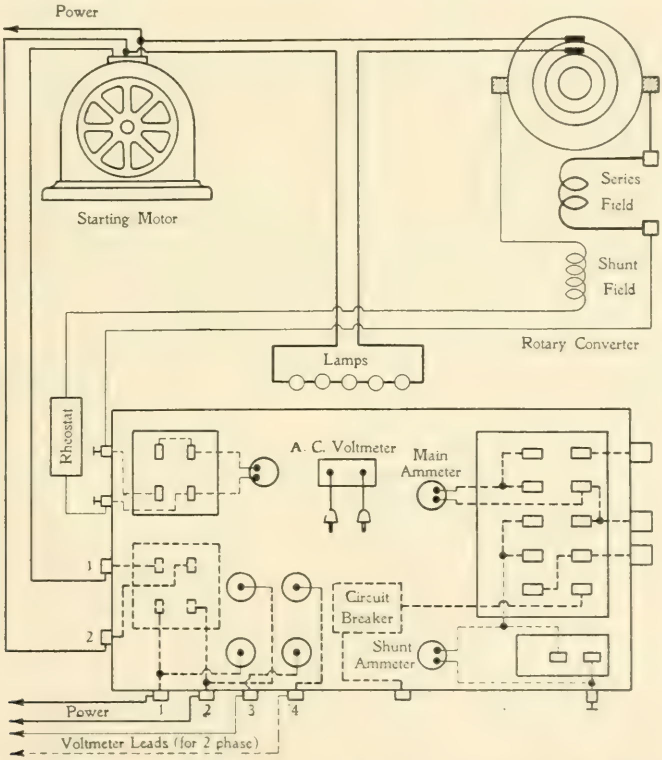


FIG. 72—CONNECTIONS FOR STARTING A ROTARY CONVERTER BY MEANS OF AN INDUCTION STARTING MOTOR

terminals of the starting motor and the slip rings of the converter as shown. There must be a sufficient number of lamps to stand double the voltage of the rotary converter, since this voltage will obtain at maximum out-of-phase positions. Before starting, the brushes should be set on the neutral position and their tension adjusted to a specified amount, generally three pounds each.

Conduct of Test—The motor starting voltage has first to be taken. This is done with converter shunt field circuit open, different low voltages, gradually increasing, being applied to the starting motor till that voltage is found at which the motor just starts; this voltage is noted. Full voltage is then applied to the motor and it should then run up to a speed greater than the synchronous speed of the converter. The shunt field circuit of the converter is closed and its voltage is gradually brought up on open

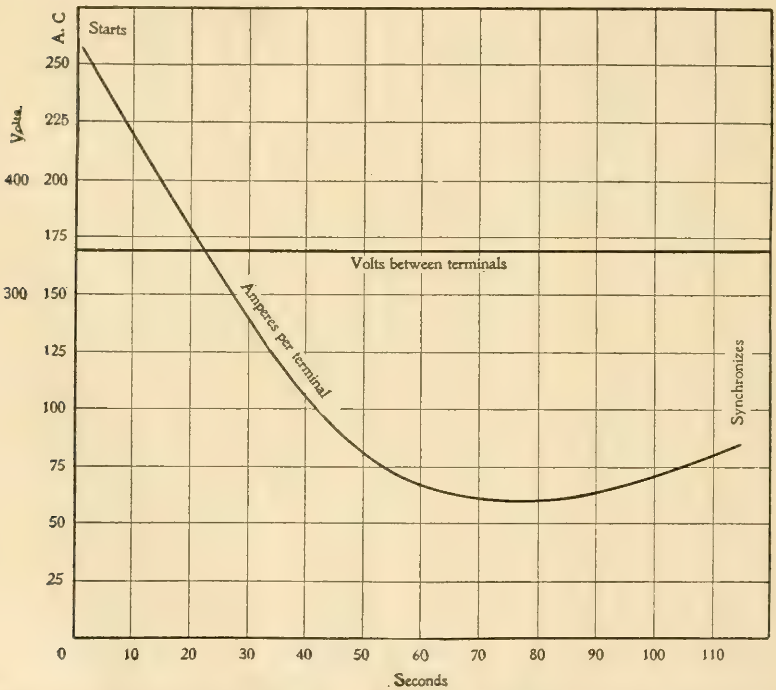


FIG. 73—TIME-CURRENT CURVE OF A STARTING MOTOR STARTING A 1 000-KW, THREE-PHASE, 550-VOLT, 25-CYCLE ROTARY CONVERTER

circuit, being measured on the direct-current side. As this is done the iron-loss increases, increasing the torque required to drive it. The result is that the converter slows down gradually. As synchronous speed is approached, the lamps will begin to flicker and this flickering will become slower and slower as the speed becomes more and more nearly that of synchronism. When synchronism is reached, the shunt field current and the direct-current voltage of the converter are read and also the voltage on the starting motor.

A check on the starting voltage should then be made to see whether the friction losses have changed.

Tests are sometimes made noting the time taken for the starting motor to synchronize the converter, under given conditions: the starting motor current being plotted to the time. In this case, the ordinary polyphase table is used, connections being made as in former tests. An example of such a curve, for a 1 000 kw, three-phase, 25-cycle, 550-volt (direct-current) 8-pole rotary converter is shown in Fig. 73.

(5) Input-Output Efficiency—This test is made by running the converter on load under running conditions and measuring the input on the alternating-current side and the output on the direct-current side. The ratio of the latter to the former gives the efficiency of the converter. In all cases the power-factor of the converter is held at unity by adjusting the field current. The loading will be done in exactly the same way as in a test of a direct-current generator. The converter is run up to speed by means of its starting motor and synchronized as in the case of a synchronous motor. Vol. I, p. 675. This test is made only in the case of small converters, the power necessary to fully load a large converter being prohibitive.

The efficiency may also be found from losses in the same way as for a direct-current generator. It is generally calculated for a constant field current and hence, a constant iron-loss. The losses found from the loss test are taken for different loads on the direct-current side and added to the direct-current output. The ratio of output to output plus losses is of course the efficiency. The only essential difference between this calculation and that for a direct-current generator is in the copper loss. In figuring the copper loss in a rotary converter, the equivalent currents in the table given at the bottom of page 182, Vol. II, are used instead of the load current.

(6) Temperature Tests—It is unusual to make a full-load temperature test, except on small converters, for obvious reasons. Where a full-load test is made the converter is run under working conditions on resistance load. A test is often made of the machine on open-circuit with an excess field current just as in the case of alternators.

FOURTH ANNUAL BANQUET OF THE APPRENTICES OF THE ELECTRIC COMPANY, MARCH 4, 1905

FROM AN APPRENTICE'S STANDPOINT

THE fourth annual banquet of the Westinghouse apprentices passed off pleasantly and successfully on the evening of March fourth at the Monongahela House, Pittsburg. Some one hundred and forty apprentices and their invited guests sat down to dinner, making it the largest and most enthusiastic gathering of the kind yet held.

Mr. Scott presided as toastmaster for the evening and called on Mr. Taylor, Mr. McFarland, Mr. Carleton, Mr. Young and Mr. Downton for remarks pertaining to the interests and working conditions of the apprentices. These gentlemen recited various experiences in their own careers and extended many kindly words of advice and encouragement to the apprentices gathered at the banquet, and in a general way explained and pointed out the great opportunities that are offered to young men on coming to work with the company. They particularly urged the men to calmly do the work thoroughly that is set before them each day; not to worry about the future, but to accomplish completely those things of the present.

Several others spoke, among whom D. O. Hales, an apprentice from New Zealand, gave his impressions regarding the American apprenticeship system. Mr. Hales responded in part as follows to the toast THE APPRENTICE, HIS WORK AND HIS FUTURE.

"Shortly before leaving my own country I received the following letter from an English electrical firm:—

Dear Sir:

We are in receipt of your letter of the 21st of October. We are in the habit of taking pupils. Most of our pupils come at ages varying from 18 to 22 and remain with us for three years, our terms being as follows:

Premiums for a three years' course, £300, payable in two installments, £150 at the conclusion of a month's trial and the remainder one year afterwards.

The pupils go through the whole of our workshops, including erecting and machine shops, armature shop, arc lamp department, smiths' shop and foundry; also the testing department, power department, drawing office, etc.

We should require a month's trial from an intending pupil, and have a vacancy at the present time.

Yours, etc.,

———— & Co.

"Fifteen hundred dollars premium and three years to work. This is the English system of apprenticeship. Let us compare it with the American system.

"After coming to this country I entered the apprenticeship course of a large company which was not only going to give me fifteen hundred dollars worth of instruction, but was going to pay me while receiving this experience. I found a special department under the official charge of a foreman working as a part of the great system. I was to be sent from department to department, I was to be placed alongside skilled workmen; I was to observe their work, to question them about it, to do the work myself.

"I had not been long on the course before I found that there was now and then dissatisfaction felt by some of the apprentices: 'Things don't go to suit us, the foremen are not appreciative of our talents. We want to go on test and no notice is taken of our complaints, we are treated just as if we were machines.'

"Where did the fault lie? Was it with the system or was it with the men?

" 'The foremen are inappreciative.' Perhaps at first! They perhaps have had too many disgruntled men loafing under them to hail a newcomer as anything out of the ordinary, and it usually takes some time to establish an understanding. But it was always my experience that when the foreman came to know his men, they were fairly treated.

" 'The departments are wrong.' Every one could not be in the busy or attractive sections at one time, and if you happened to be in a slack section, there were not serious objections raised to your going over to another department at odd times to see what you could learn by observation; provided always that you did not hinder men who were at work or turn your visit into a social call on an old college chum. It was annoying on test, to ask a fellow apprentice to go behind the board and plug in the rack for you, and then, on receiving no answer to your signals, to find him with his back towards you enjoying a chat with two or three old college mates.

"Everyone has his own idea of what things are most beneficial to him. On a recent visit to my old school I was asked what were the most important points to be found in connection with our apprentice course. I answered: First, I have had the chance of being a unit in a great organization and of observing some of the details of that organization. Second, I have come into personal contact with men who have distinguished themselves in engineering and scientific work. And third, I have worked with the working man as a working man.

"The advantages accruing from the first two will be evident to all and it is of the third I wish to speak when I refer to the future of the apprentice. By future I do not mean the days immediately following the close of your apprenticeship course, when your talents have won worthy recognition, but to the days when you have taken a place in the world, either as engineers in some organization or as business or public men.

"In a country such as this, where your national games are played by men at college or by professional athletes, and where the spirit of commercialism has so crept into your sports that a ten year old youngster *signs on* to his baseball team and will hardly travel three blocks to play a game unless some one guarantees his expenses, you do not have the advantages of seeing the working man at his best and worst that we have in our more favored land. There Saturday after Saturday during the summer, the merchant, the manufacturer or the banker can be found playing cricket with or against his clerks or mechanics; and during the winter the engineer, the lawyer, the mechanic, the butcher, the baker and the policeman may be all mixed up in the friendly tussle of a football match. But your work during your apprentice course gives you a great opportunity for studying the working man.

"You may become managers of great businesses, you may have the handling of scores of men, but you will never have the same opportunity to acquire sympathy for labor as when you work with the working man as a working man; and when I say working man I do not take the broad academic meaning of the term, but the narrow view, the working man as a man who does manual labor for hire.

"You, as future managers of labor, must study the question, not only by personal observation, but by learning what is being done in other lands, in Germany, in England, in Australia,—where the labor party controls the senate and holds the balance of power in the House of Representatives—and in my country (New Zealand) where the labor party has recognized that setting class against class is not for the good of the community, and by their votes have kept in power a ministry composed of men, no laboring men, but who nevertheless have been able to do much for the cause of labor.

"In this country the labor unions are frowned on by the capitalists and manufacturers. Unions have usually brought industrial warfare and industrial depression.

"As time goes on the factory work hours must become as short

as what are now known as office hours, and when that time comes, you, as managers of labor, must find some better way for your working men to spend their hours of recreation than by loafing around a filthy town where the sole attractions are saloons. You must find some more chivalrous way of treating your female workhands than turning them out to fight for trolley car seats against a crowd of hungry men eager to get home. These things may appear to be outside the interest of the manager or employer of labor; but you have only to go over to Allegheny and see the work being done by the Heinz Company or to remember our own Electric Club and Casino classes to find that some employers do not consider an interest in the leisure hours of their employees to be wasteful and unproductive.

"Gentlemen! In your apprentice course you can learn more than practical engineering. You are under a great leader, you can catch some of the spirit of that leader. You can build up your life character of fame in your profession that your influence will be so felt by your fellowmen that when your final account is settled, your family may take pride in the knowledge that they, your neighbors, your community, even your country, are the better for your having lived and worked in their midst."

TAPING

BY C. STEPHENS

THE PURPOSE OF TAPE

THE most obvious use of tape is to provide a permanent mechanical separation of conducting materials, and to maintain a gap between two conducting wires, or a wire and the ground, which might be done by any non-conducting material, even wooden blocks. A good quality of tape, however, not only prevents the lodging of small conducting particles and dirt, but actually increases the dielectric strength of the gap. In other words, a good insulating tape will considerably increase the effective length of an air gap. For instance, ten thousand volts will puncture an air gap of approximately one-quarter of an inch between spherical terminals. If the same air gap be filled with impregnated linen tape, more than 40 000 volts wil be required to puncture. A sheet of treated cloth

.01 inch thick will stand a puncture test of from four to ten thousand volts, while ten thousand volts will puncture almost one-half an inch of air between needle points.

KINDS OF TAPE

Generally speaking there are three classes of tape—(1) untreated cloth, (2) rubber, (3) treated cloth.

Untreated cloth tape may be of any fabric, such as linen, cotton or silk. When this tape is kept perfectly free from moisture it forms a good insulation. Its chief advantage, however, is its mechanical strength, which admits of rough handling during the taping process. After it is in place it is usually treated by brushing with or dipping in varnish or some other insulating compound. This increases the dielectric strength and prevents the absorption of moisture.

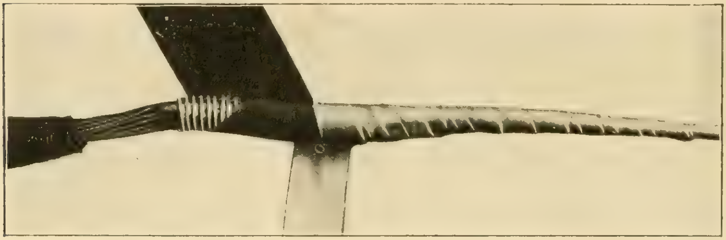
Rubber tape may be divided into two general classes, (1) those tapes without any cloth or other supporting body, (2) those with some supporting body. The first class of rubber tape is made up from a rubber compound. It is relatively thick, but being quite elastic, the operator is enabled to obtain varying thicknesses by stretching. It is best adapted where the voltage is high and where there is plenty of room for insulation. In splicing rubber covered cables this tape secures for the splice practically the same insulation as is on the body of the wire. The second class of rubber tape may be obtained in a variety of forms, the most common of which are viscous tapes. These tapes are sticky at ordinary temperatures. They adhere readily and, after drying for some time, become quite hard and offer considerable mechanical support. Viscous tapes vary considerably in thickness and cost, depending on the materials used in their manufacture.

Treated or varnished cloth tape may be sticky, or it may have a smooth, hard surface; it usually requires some binding material to hold it in place. Its insulating property is very high and, being very thin, it is well adapted where space is valuable, especially in insulating wires in slots of machines. However, it is not very strong mechanically and should not be used on rough or uneven surfaces, or where it is likely to be subjected to mechanical strains.

MOISTURE PROTECTION

A taped joint or conductor should be moisture proof. To insure this the tape should be wound very firmly. A good joint should

be made between the tape and the insulation of the wire. In taping a splice the metal surface should be smoothed, using a file if there are sharp points or corners left from soldering. The surface should then be sand papered slightly and wiped with a dry cloth to remove all dirt, dust and soldering fluid. The kind of tape used in any case will be determined largely by the space in which the conductor is confined. As a rule a thin viscous tape is used on all ordinary work which is subjected to moderately low voltage. When the volt-



TAPING THE SPLICE OF A SOLID CONDUCTOR AND A CABLE

age is high and the insulating space is very limited, and especially where the conductor comes in contact with the iron parts of a machine, the conductor should be taped with treated cloth and finished with a taping of untreated cloth, and then the whole thoroughly shellaced or varnished. This method is illustrated in the accompanying figure, where it will be noticed that each layer of tape is lapped approximately half the width of the strip as it is put on. This figure also shows a very good method of soldering a cable to a solid conductor. It is well to bind the solid conductor to one side rather than to bury it entirely within the strands of the cable.

EDITORIAL COMMENT

Commercial Electrical Engineering

"He must understand more about the customer's business than the customer himself, and he must know more as to what the apparatus will do than the designer himself." Such was the reply of a man who was for a long time connected with the sales department of the Electric Company, when asked the principal qualifications essential in a commercial engineer. The man himself had handled many negotiations in which the engineering features were of great importance and he had, moreover, been in a position to observe the work of others.

The engineering work of a large electric company may be divided under two general heads; the first is the design of apparatus and the issuing of specifications and data describing what it will do, the second is the selection and application of the apparatus to specific cases.

The latter, which may be termed commercial engineering, is sometimes quite a simple matter; in other cases it is of the greatest difficulty and calls for the highest grade of engineering ability. It is not so much a knowledge of the theoretical elements involved in the design of the apparatus, a motor for example, which is needed, as a good practical knowledge of what the motor can do. This practical knowledge needs to be based upon a definite knowledge of what the motor can do on shop test, and upon good judgment—based upon experience—in the selection of a definite motor to meet the requirements under particular conditions which may be uncertain and indefinite and varying in character, an estimate which is very hard to express in amperes or horse-power.

But why should an electrical engineer or an electrical salesman know the customer's business, too?

Electrical work is seldom purely electrical. Electricity is simply an agent. It enters into other things as a means of accomplishing results. Hence, it enters into them vitally and intimately. Every department of a railway or a factory which adopts electricity may in one way or another be modified by it. Electrical engineering is related to all other kinds of engineering, steam, hydraulic, pneumatic, mechanical, civil, chemical. In order that the commercial engineer may effectively apply his apparatus and show that it can produce results, he must be thoroughly familiar with the business of which his electrical machinery is to form a part and which per-

chance it is to modify or revolutionize. Hence, the need of a fundamental all-around common sense knowledge of all kinds of engineering and all kinds of operation. Hence, the education of the engineer should not be a mere collection of facts, but a development of engineering faculties. The education of the electrical engineer in college and in the apprenticeship course should lay a foundation in the fundamental principles of different branches of engineering and in a training which will enable these general principles and general knowledge to be correctly applied in particular cases. In no branch of engineering is a broad general knowledge and the ability to apply and use such knowledge for specific purposes more necessary than in electrical engineering.

Chas. F. Scott

Underwriters' Rules

On March 8th to 11th was held a notable meeting at the Works of the Westinghouse Electric & Manufacturing Company, this being the third annual meeting of the representatives of the Underwriters' National Electric Association with the Engineers of the Electric Company for the purpose of discussing the National Electrical Code and electrical practice in their relation to the apparatus manufactured by that company. The visiting committee consisted of seven men who have a national reputation in the classes of work which they represent.

The history of the National Electrical Code is very interesting, showing as it does the progress of electrical work from its earliest beginnings until the present time. When electric lighting came into common use it was found that frequent fires resulted from poor material, improper methods of wiring, and general lack of knowledge of the necessary precautions in the installation of electrical apparatus, wires and fittings. Several fire insurance companies and many city governments instituted rules covering this work, and naturally these rules were as diverse as the bodies which promulgated them and the cities which used them. Through the efforts of some of the large fire insurance interests, these rules were finally merged, ten years ago, into the National Electrical Code. The code was not at first universally adopted, but is now recognized throughout the United States as the authority on all such matters.

That this code requires frequent revision and supplement is not surprising to those who are familiar with the wonderful changes which have taken place in the past decade in all things electrical. With the thousands of new applications of electricity, and the use

of currents and potentials which a few years ago were scarcely thought of, new safeguards and better construction have become necessary, both from the engineering and from the insurance standpoint. Materials and methods have also been so improved that rules which would have been entirely prohibitory, when the code was first issued, are now not only feasible, but desirable. As an example of the change in practice due to the above causes may be cited the modern switchboard as compared with the modern affairs of fifteen years ago.

The aim of the framers of the rules constituting the code has been to require such construction as to reduce the fire risk to an absolute minimum. All electrical apparatus, wires and appliances are looked upon as so many possible producers of fire or as contributors thereto. The very fact that the insurance companies paid last year over five million dollars for fire losses attributed to electrical causes is in itself sufficient justification for the most careful consideration of the code by those who design and install electrical apparatus.

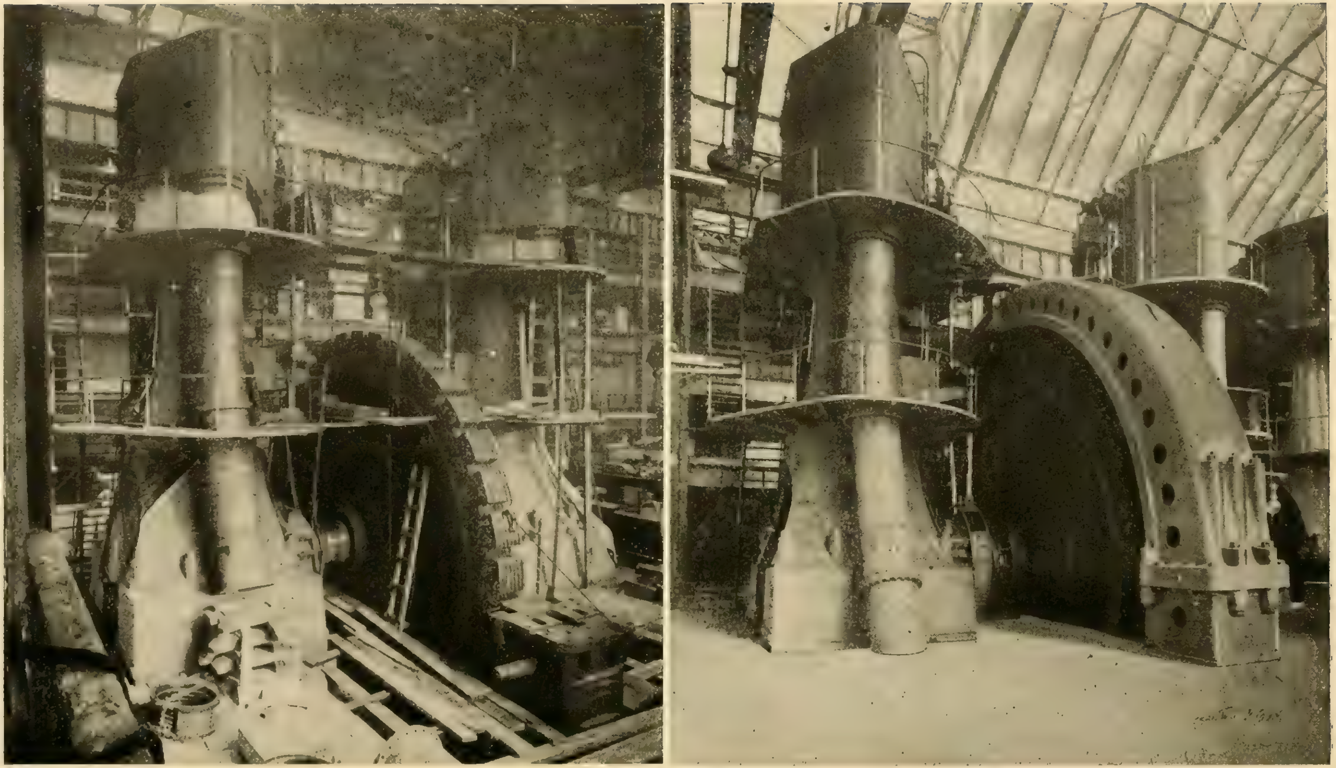
To one who has watched the trend of these rules as they have been modified from time to time and who has also had something to do with the designs necessary to meet them, the recent meeting proved that manufacturers and fire insurance people have common and not diverse interests, and that they are rapidly coming to a better understanding of this fact.

Many electrical fires prove some defect in design or material, or in the operation of the apparatus. To make apparatus that will operate satisfactorily at all times and under all conditions is the constant aim of the designing engineer. He has much to consider besides the fire risk caused by the improper use or abuse of the apparatus which he designs. Fires may be caused by accident or abuse of the best apparatus which can be designed. To prevent fires from electrical causes is the sole reason for the framing and enforcement of the rules by the underwriters. As to ways and means there will, of course, always be honest differences of opinion, but such meetings as the one recently held cannot fail to bring about a better understanding on each side, and to show each that the other frequently has just cause for his different opinion.

Unfortunately, the ideal, universal, non-absorptive, non-combustible insulating material is yet to be discovered, and until this is found the judgment and experience of those who design and install

the apparatus and those who make and enforce the rules must be combined to give the best results. Rules which are practicable and which are uniformly enforced do not entail unreasonable hardship, as all are affected alike.

C. E. Skinner



A 5 000 KW UNIT OF THE INTERBOROUGH RAPID TRANSIT COMPANY, NEW YORK, DURING CONSTRUCTION AND AS IT NOW APPEARS

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TEST OF A 5 000 KW ALTERNATOR

By L. L. GAILLARD

Electrical Superintendent with the Interborough Rapid Transit Company, New York.

THE following paper is intended to give a general description of the series of tests made on each of the alternators installed in the 74th Street (Manhattan) power station of the Interborough Rapid Transit Co., of New York City. The object of the tests was to obtain characteristic curves of the machines and to determine how nearly they conformed to the contract requirements and the manufacturer's guarantee.

Each machine is a 5 000 kw., 11 000 volt, 25 cycle, 75 r. p. m. Westinghouse alternator, direct connected to a double horizontal-vertical Allis compound engine.

It may be well to preface the account of the tests with the following extracts from the contract specifications giving certain data obtained from the calculations of the manufacturer, and certain guarantees upon which was based the acceptance or rejection of the machine by the purchaser.

A guaranteed full-load efficiency of 96.5 per cent., to meet which guarantee the total permissible losses in the alternator are therefore 181,300 watts.

The full-load field current equals	202.	amps.
The full-load armature current equals	263.	amps.
The armature copper loss equals:		
$263^2 \times 0.4 =$	27667.	watts.
The field resistance equals	0.85	ohms
The resistance of the armature equals	0.4	ohms
The field copper loss equals:		
$202^2 \times 0.85 =$	34683.	watts.
Total copper losses =	62350.	watts.
Total allowable iron losses, based on 96.5 per cent. full-load efficiency, =	118950	watts.

The efficiency on non-inductive load will be:

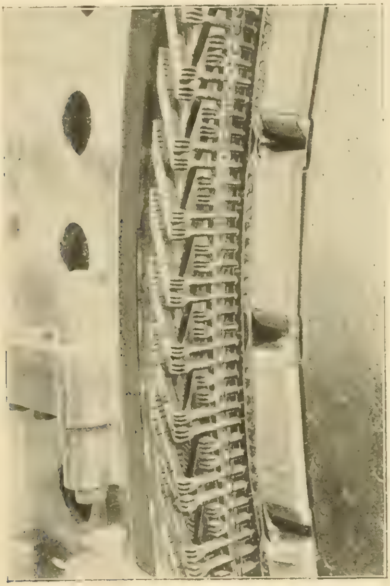
At one-quarter load = not less than	90.00	per cent.
At one-half load = not less than	94.50	"
At three-quarters load = not less than	95.50	"
At full-load = not less than	96.50	"
At 25 per cent. overload = not less than	97.00	"

The efficiencies are based on I^2R loss in the armature and field coils and on the armature iron loss. Friction is not included.

The current in the armature when short-circuited with normal no-load field current, will equal three times full-load current.

The regulation at 100 per cent. power factor will equal 6 per cent.

After running for 24 hours at full-load at 100 per cent. power factor, the rise in temperature in no part will exceed 35° C.; and at 25 per cent. greater load, with the same power factor, for twenty-four hours, the rise in temperature will not exceed 45° C.



ARMATURE END CONNECTIONS SHOWING THE WOODEN BLOCK BRACING BETWEEN THE COILS

The following measurements and tests were made on the alternator:

Measurement of armature iron loss.
Resistance of armature winding.
Resistance of field winding.
I^2R loss in armature.
I^2R loss in field.
Efficiency at various loads.
No-load saturation curve.
Short-circuit characteristic.
Regulation (calculated).
Insulation puncture test.
Temperature rise under load.

Armature Iron Loss — It being entirely impracticable to measure this loss in the usual manner, the following interesting method was adopted:

The alternator armature is built up of the following amounts of sheet steel worked at magnetic inductions given below:

234,000 cu. in.,	90 per cent. solid,	@ 65,500	C. G. S. lines per square inch.
16,500	"	@ 91,100	"
20,300	"	@ 76,500	"

The iron losses were determined from a measurement of the losses in sample rings made from the material of which the armature was built up. These samples were annealed in the ovens with the armature laminations, were painted the same as these laminations, and then built up into test rings and compressed until their volume contained 90 per cent. solid metal. The rings were then wound for test purposes and the losses at the different inductions mentioned above, were measured with a sensitive wattmeter.

The dimensions of the test samples were: outside diameter, 12 inches; inside diameter, 8 inches; thickness (compressed to 90 per cent. solid) 2 inches; cross section, 2 in. x 2 in., 4 sq. in.; mean circumference, 31.416 inches; volume, 125.66 cu. in.

The calculations of 90 per cent. solid material in samples were based upon specific gravity tests made on samples cut from the steel bars from which the sheets were rolled. The average specific gravity of several samples was 7.847, which gives 3.91 cu. in. per pound for 90 per cent. solid material. The weight of the sample, on the basis of these calculations, should therefore be 32.13 pounds.

LAMINATED RING AND CLAMPING DEVICE FOR DETERMINING THE QUALITY OF THE IRON USED IN THE MANHATTAN ALTERNATORS AND THUS THE TOTAL IRON LOSS

About twenty sample rings were built up and each sample was wound with 72 turns of No. 18 B. & S. annunciator wire, wound in 12 groups of one layer, and six turns each, with the groups symmetrically disposed around the circumference of the ring.

The iron loss in each sample was measured at each of the three inductions mentioned above, viz.:

	C. G. S. Lines per sq. inch.		C. G. S. Lines per sq. cm.
(a)	65,500	=	10,155
(b)	91,100	=	14,124
(c)	76,500	=	11,860

The voltages required for each of the three inductions at 3 000 alternations were obtained from the following calculations:

B = Maximum induction per sq. cm. t = Number of turns.
E = Effective volts. a = Sectional area in sq. cm.
n = Periods per second. $E = \pi\sqrt{2}\, a\, n\, t\, B\, 10^{-8}$.

Reducing this formula to area in sq. in. and alternations per minute, we have

$$E = .2388\, a'\, n'\, t\, B\, 10^{-8}.$$

Where a′ = sectional area in sq. in. = 4
n′ = alternations per minute = 3000.

The voltage at the various inductions is then as follows:

(a) $E = .2388 \times 4 \times 3.000 \times 72 \times 10.155 \times 10^{-8}$ = ... 20.96
(b) $E = .2388 \times 4 \times 3.000 \times 72 \times 14.124 \times 10^{-8}$ = ... 29.15
(c) $E = .2388 \times 4 \times 3.000 \times 72 \times 11,860 \times 10^{-8}$ = ... 24.48

The losses in the samples were measured by carefully calibrated instruments, and the alternator used for supplying current for the purposes of the test gave a wave of almost exactly sine form.

The average results of measurements on the twenty samples was as follows:

(a) 0.1340 watts loss per cu. in.
(b) 0.2320 watts loss per cu. in.
(c) 0.1724 watts loss per cu. in.

The total watt loss in the armature was, therefore, as follows:

(a)	234,000 x 0.1340 = ...	31,380 watts.
(b)	16,500 x 0.2320 = ...	3,821 "
(c)	20,300 x 0.1724 = ...	3,492 "
	Total	38,693 watts.

The impracticability of making an accurate determination of the iron losses after the machine had been assembled is to be regretted, as the method adopted and just described contains probabilities of error which cannot be pre-determined or eliminated. The armature casting is made in six sections and the sheet steel laminations are each no greater than six feet in length, thus making in the magnetic circuit six butt and numerous lap joints. The losses due to these breaks in the magnetic circuit are of course neglected when the determination of the iron losses is made in the manner just described, but it is probable that they are of so small a value when compared with the total losses as to be negligible.

Resistance Measurements of Armature and Field—These measurements were made by the usual drop-of-potential method, the temperature of the winding and of the room being observed. The resistances as measured were then calculated for a room temperature of 25° C. and the I^2R losses calculated on this basis.

Resistance of Armature:

Phase 1—2 R = 0.2325 ohms at 25 degrees C.
" 2—3 R = 0.2332 "
" 1—3 R = 0.2329 "

2 times combined resistance of three phases =
0.2325 + 0.2332 + 0.2329 = 0.6986.

Total armature resistance therefore equals

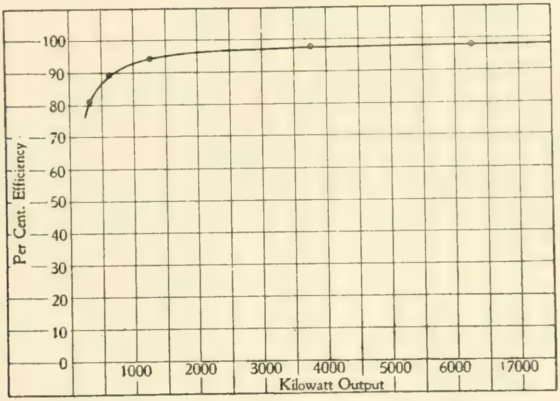
$\frac{0.6986}{2} = 0.3493$ ohms.

Resistance of field at 25° C. = 0.8206 ohms.

Efficiency—As noted above the efficiency is based on the armature iron losses and the field and armature I^2R losses. The iron losses were determined as described above, and from the

resistance values as obtained by measurement, the I^2R losses in field and armature have been calculated for various loads from 25 per cent. to 125 per cent. of full rated load. These appear in tabulated form below, and following in a curve plotted from the calculated efficiencies.

In calculating the field I^2R loss, 208.1 amperes was used as full-load field current, this value being obtained in the following manner:



EFFICIENCY CURVE OF A 5 000 KW 11 000 VOLT MANHATTAN ALTERNATOR

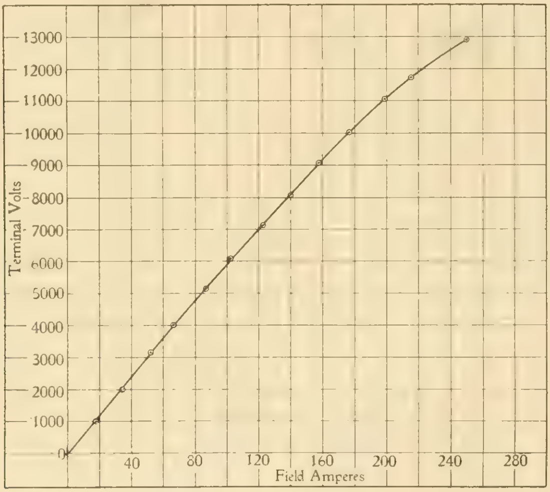
Field current corresponding to terminal voltage on open circuit plus armature resistance drop = ...	198.5	amps.
Field current necessary to give full load armature current or short-circuit, = ...	62.5	"
Full-load field current is the vector sum of above, or	208.1	"

	1/4 Load.	1/2 Load.	3/4 Load.	Full Load.	1 1/4 Load.
Iron Loss.........KW.	38.69	38.69	38.69	38.69	38.69
Arm't're I^2R Loss "	1.51	6.04	13.59	24.16	37.75
Field I^2R Loss... "	35.54	35.54	35.54	35.54	35.54
Total Losses..... "	75.74	80.27	87.82	98.39	111.98
Output .... "	1250.	2500.	3750.	5000.	6250.
Input .... "	1325.74	2580.27	3837.82	5098.39	6361.98
Efficiency.....per cent.	94.29	96.50	97.71	98.06	98.24

No-Load Saturation—The no-load saturation curve was obtained in the following manner:

The alternator field was excited from a 250-volt steam driven generator running at constant speed. The alternator, with its armature circuit open, was brought to full speed with the engine on the throttle, and held at this speed while the

measurements were made. Simultaneous readings of volts field, amperes field, volts armature and speed were taken. The instantaneous readings of speed were made by means of a frequency indicator which had been previously carefully calibrated. Below is given in tabulated form the instrument readings from which the saturation curve has been plotted. As some of the readings were taken at a frequency higher than 25 cycles (due



RUNNING SATURATION OF A 5 000 KW 11 000 VOLT MANHATTAN ALTERNATOR

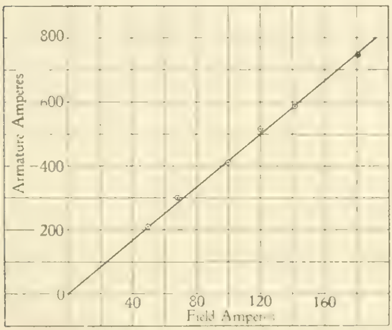
to the engine speeding up), the armature volts at these points were corrected for this difference in speed by decreasing them in proportion to the increase in speed.

Frequency	Amps. Field	Volts Field	Volts Armature	
			Observed	Corrected
25.0	17.5	15.3	1,000	1,000
25.0	33.5	29.4	1,963	1,963
25.0	51.4	44.8	3,140	3,140
25.0	66.0	57.3	4,010	4,010
25.0	86.0	74.5	5,150	5,150
25.0	101.8	87.3	6,100	6,100
25.2	121.8	103.5	7,190	7,133
25.2	139.0	117.8	8,120	8,055
25.2	157.2	134.8	9,150	9,077
25.2	176.2	150.0	10,100	10,019
25.2	198.0	168.5	11,160	11,070
25.5	214.0	183.0	11,970	11,640
25.2	249.2	218.0	13,020	12,916

Short-Circuit Characteristic—For this test the armature terminals were short-circuited, the alternator run at full speed and the armature current measured at different values of field current. The tabulated readings and the curve plotted from them are given below:

Speed R. P. M.	Field Amperes.	Field Volts.	Armature Amperes.
75	50.0	36.0	210.0
75	68.0	50.0	300.0
75	100.0	74.5	411.6
75	120.2	89.5	516.0
75	141.2	105.5	588.0
75	181.0	140.5	744.0
75	193.3	158.0	798.0

Insulation Test—The contract specifications required that after the machine had been assembled the insulation of the field winding from the frame should be subjected to a puncture test of 2 500 volts alternating e. m. f. for a period of one minute, and that the insulation of the armature winding from the frame should be tested at a potential of 25 000 volts for thirty minutes.



SHORT-CIRCUIT CHARACTERISTIC OF A 5 000 KW 11 000 VOLT MANHATTAN ALTERNATOR

As the armature coils had been exposed to moisture for some time before being assembled, it was thought advisable to give them a drying out before subjecting them to the puncture test. For this purpose the armature was short-circuited and the machine run at about two-thirds full speed with sufficient field current to give about 500 amperes in the armature. This heat run was kept on for about sixty hours, then the machine was shut down and the windings carefully wiped off and allowed to cool to the temperature of the room before the insulation test was made.

The insulation tests were made by using a 250 kw, 40 000:360 volt 25 cycle oil-cooled transformer, the low tension winding of which was connected in series with a water rheostat, to the 400 volt, 25 cycle station bus bars. The potential on the

high tension side of the transformer was measured with a 50 000 volt electrostatic voltmeter which had been previously calibrated.

It may be of interest to note that when the test potential was first raised to 25 000 volts, and for some minutes thereafter, a considerable static discharge was noticed taking place over the surface of the windings. As the test was prolonged, this static gradually decreased in intensity until after the lapse of about twenty minutes it almost entirely disappeared.

Regulation—The specifications for this machine provide that "a load of 263 amperes per terminal at 11 000 volts e. m. f. and at 100 per cent. power-factor may be thrown off, and the e. m. f. will rise six per cent. with constant speed and constant excitation."

It has not been found convenient to make an actual measurement of the regulation of the machine, but from the data and characteristic curves it has been calculated. This calculation was made by the usual magnetomotive-force method and the regulation was found to be 4.5 per cent. This figure is undoubtedly too small as this method of calculation invariably gives results more favorable to the machine than those obtained from actual test.

Temperature Measurements—A number of determinations of the temperature rise in field and armature conductors and in armature laminations were made after the machine had been running under load for a sufficient length of time to have reached a constant temperature.

The following results represent the average rise in temperature above the surrounding air of the various parts of the machine after a run of seventeen hours at an average load of 5 000 kw.

Temperature rise above air:

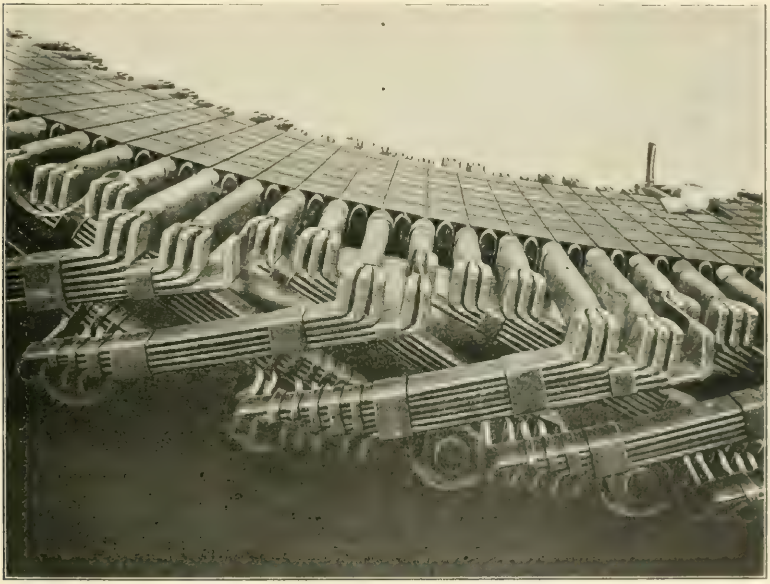
Field winding	22.°5 C
Armature winding	22°6 C
Armature laminations	25.°5 C

The performance of the eight alternators, of which this one is representative, has been so excellent and the temperature so greatly below the guarantee, that their rating has been increased from 5 000 to 6 000 kilowatts.

Testing Synchronizing Connections—After the first machine had been installed it became necessary to make sure of the correctness of the synchronizing connections of each of the others

as it became ready for operation. For synchronizing, dark lamps and a dial synchronizer are used.

To make an absolutely certain test of the synchronizing connections, the following interesting method was adopted: When the second machine was ready for service, the main switches of both Nos. 1 and 2 were closed, tieing the machines to the bus. Full-load field current was put on each alternator and both engines were started simultaneously and slowly brought to full speed together. If the lamps remained dark and



END CONNECTIONS OF THE ARMATURE WINDING

the synchronizer indicated exact synchronism, no better check could be had on all connections. Had there been any wrong connections in the armature circuit of one machine, making a short-circuit when the two machines were tied together, this would have been indicated on the ammeter in the armature circuit immediately after the machines started. The relay would also have operated immediately to open the armature switch.

After the two machines had been brought to full speed (tied together) they were then cut apart and synchronized in the usual manner. This method was used with great success on all the machines, a separate bus-bar being used for the purpose.

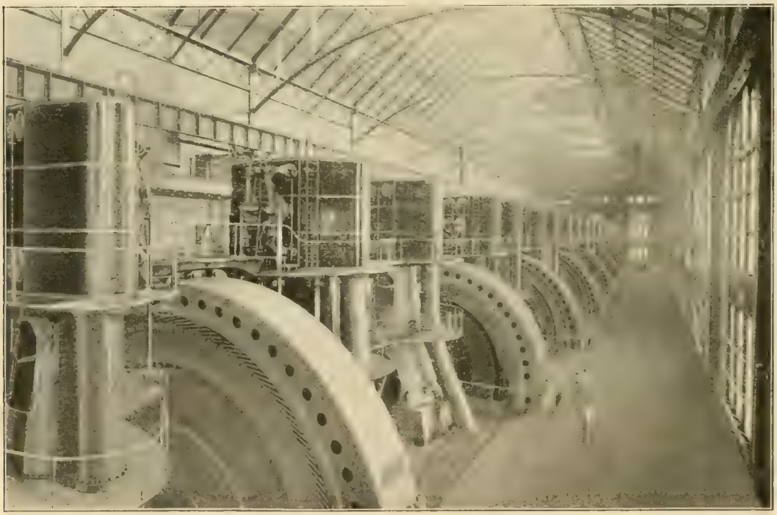
INCIDENTS IN THE OPERATION OF A LARGE POWER PLANT AND DISTRIBUTION SYSTEM

By H. G. STOTT

Superintendent of Motive Power of the Interborough Rapid Transit Company, New York.

PROGRESS in engineering has been due to two forces which usually act in the same direction, viz.: Invention and Experience. Sometimes these forces get a little out of phase but the resultant is invariably in the direction of Progress.

Invention usually comes from the engineering forces of the manufacturer and experience from the engineers of the operating companies and, accordingly, to-night I am going to try and give some of our experiences so that the younger members of



INTERIOR OF THE 74TH STREET STATION OF THE INTERBOROUGH RAPID TRANSIT COMPANY, NEW YORK

The Electric Club who, almost without exception, belong to the first class of forces, may continue to co-operate in the work in which the senior members have been so conspicuously successful.

The incidents hereafter mentioned all occurred in the 74th Street plant and transmission system of the Interborough Rapid Transit Company of New York.

I will only give a brief outline of the apparatus in this plant, as many of you are already familiar with it.

The power plant contains eight 5 000 kw, three-phase, 25-cycle, 11 000 volt engine-driven alternators and one 5 500 kw, turbine-driven alternator, all of them having a 50 per cent. overload guarantee which has been fully borne out in practice, as we have frequently carried 100 per cent. overload on them. The switchboard apparatus consists of the now standard distance control board which operates oil switches governing the generators and feeders.

The transmission lines consist of about 150 miles of underground, lead covered, three-conductor cables, about 90 per cent. of them having paper insulation and the balance rubber or oiled linen. These transmission lines are from two to seven miles in length and supply seven substations, each substation having from four to six cables running directly to the power house. In the substations are installed 41 1 500 kw rotary converters, which, with their transformers, convert the 11 000-volt, three-phase current into 625-volt direct current which is delivered to the contact rails of the elevated railroad. Oil switches are used for the alternating-current control, similar in every respect to those in the power house, there being an oil switch on each feeder and also on the high tension side of each set of transformers supplying the rotary converters.

All feeders to a substation are run in multiple at both ends.

After this brief resumé we will now proceed to note some incidents in the operation of this plant during the three and a half years it has been in operation.

August 14, 1902:

At 12:30 p. m. the station was shut down for 5 minutes. A temporary railing had been placed around the armature windings of each generator in order to keep people away and one of the oilers sat down on the top of the railing, although warned by a foreman of another department of his danger; apparently he leaned backwards until his back touched the end connectors of the armature winding and either his hand or foot touched the generator frame. The man was instantly killed and an arc established between the end connectors and the grounded frame, causing a short circuit on the machine and bus, which tripped out the oil switches on the two generators running. The short-circuit

damaged about twenty of the armature bars, bending them and breaking the insulation where the bars leave the laminations. The short-circuit occurred near the terminals of the generator, so that practically full voltage acted across the phases.

This was a case against which it is exceedingly difficult to provide, except by the enforcement of rigid discipline and the education of employes and, as this is a matter of time, it is always difficult to accomplish during the initial stages of the operation.

September 30, 1902:

At 12:24 a. m., generators No. 5 and 6 were running and No. 5 was about to be cut out owing to the load having fallen to a single engine load, the throttle valves of No. 5 were almost closed preparatory to the switchboard man cutting out the generator. The latter, in mistake, cut out No. 6 instead of No. 5, thus throwing about 6,000 kw on No. 5 which, of course, shut down before the blunder was discovered, thus shutting down the entire system. This is one of the mistakes liable to occur, due to the personal equation, which can be provided against only by elimination of the employee who shows carelessness in his work.

December 18, 1902:

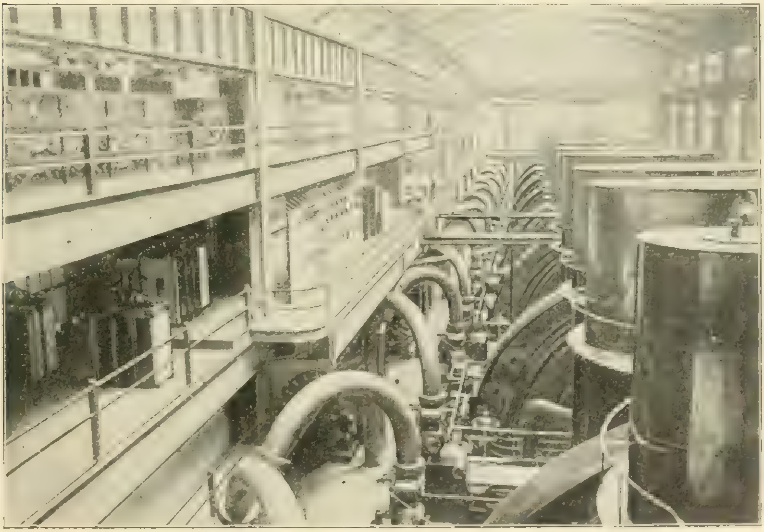
At noon, rotary converters C and E in the power house were carrying the auxiliary load including the air pumps on the jet condensers; at this time rotary converter C short-circuited in the armature and dropped the potential on the other machine so that all the condenser motors shut down. This resulted in all the engines losing their vacuum and exhausting into the atmospheric discharge pipe and setting up enough back pressure to force the exhaust steam up through the air pumps into the discharge tunnel and there, after lifting the manhole covers, escaped into the engine room. The entire basement became so full of this wet steam that it was unsafe to run the generators any longer and they were being shut down when No. 8 short-circuited near the terminals, destroying about one-fourth of the windings.

At the time this accident happened the condensing system was being redesigned so as to eliminate the motor drive and substitute steam-driven circulating pumps and the barometric tube type of condenser for the electrically driven jet condensers with the object of rendering impossible such an accident as this and at the same time obtaining various other advantages.

Electrically driven boiler feed pumps, air pumps, exciters and circulating water pumps, are not advisable in a power plant from any point of view as they form a link in a chain and any one of these links may be the means of shutting down the entire system. Investment, thermal efficiency and reliability all indicate steam-driven auxiliaries for power plants.

July 24, 1903:

At 5:45 p. m. the foreman of substation No. 7 telephoned that he noticed a heavy static discharge on cables at that station. Immediately afterwards the foreman of substation No. 8 made a similar report. The operator in charge at the power house



INTERIOR OF THE 74TH STREET STATION OF THE INTERBOROUGH RAPID TRANSIT COMPANY, NEW YORK

went to the cable gallery to examine the static discharges in order to locate the trouble; while there, a loud explosion occurred on 74th street, which proved to be in one of the manholes in the street into which the cables come after leaving the building.

Within a few seconds No. 4 generator short-circuited across the end connections, some of these connectors being forced out of place over five inches, until they struck the armature frame. Practically every connector and bar of one phase was bent out of shape in this machine and a great many on the other five generators which were in multiple with it.

Simultaneously nine of the underground high tension feeders were punctured or short-circuited in from one to three places each and a number of static dischargers destroyed.

The origin of all this trouble seemed to be in a joint in one of the underground cables in a manhole just outside the power house. This cable first grounded in a joint on one phase which was within 150 feet of the bus bars in the power house, causing the exhibition of static discharge noticed in the substations and, shortly afterwards, burned off the insulation of the other two phases and so formed a short-circuit. At the time this short-circuit occurred six generators were in operation, all being in multiple, and as each one can give out 350 per cent. of its full-load current on short-circuit there was probably 100 000 kw concentrated upon the short-circuited joint from the power house and at least 50 per cent. more concentrated upon it by the stored energy of the 35 1 500-kw rotary converters which, of course, immediately become generators when the voltage on the system drops suddenly. About four feet of the cable was burned off in the manhole and the sudden heat developed by 150 000 kw being expended in an arc in a space about 10 feet by 8 feet resulted in a sudden expansion of the air which lifted the entire top off the manhole, as well as the pavement surrounding it.

This alternating-current arc, not being confined, undoubtedly set up violent oscillations in the system which, from the distance the arc jumped and from calculations made by Mr. C. P. Steinmetz based upon the constants of the circuits, must have raised the instantaneous pressure to a point in excess of 115 000 volts.

The lessons taught by this disastrous rise of potential, which shut down the entire system for 25 minutes, were as follows:

First: All cables must be so installed that a short-circuit between phases or between phases and ground cannot establish an open air arc, or, in other words, the arc must be confined to as small a space as possible, such as inside a tile conduit or iron pipe.

As practically all cables are pulled into conduit of some description it follows that the danger spots will be the manholes where the cables leave the conduits. Special means have been taken to enclose all the cables in the manholes.

Second: Static dischargers as ordinarily installed are incapable of handling large rises of potential when backed by a large

amount of power. They may readily be the cause of great delay in restoring power after they have burned out, as they did in this case.

In order to install enough static dischargers it would probably be necessary to put up a separate building to contain them and as this is not generally feasible we decided to remove them entirely.

Third: The armature bars were evidently not sufficiently supported outside the iron to stand the dynamic forces of repulsion and attraction where the coils or end connectors are parallel to one another. This has been very successfully overcome by the hard wood blocking shown in Fig. 2. Examination, after several severe short-circuits sustained since the introduction of this blocking, shows that the windings are now quite rigid and secure, and capable of successfully standing any strain produced by the most severe conditions possible.

Other experiences of a somewhat similar nature have been met with but time will not permit of their introduction here.

In conclusion I would like to point out the great importance and benefit to both the manufacturer and user of the apparatus of keeping in close touch with one another so that our joint efforts in the direction of progress in electrical engineering may be more and more in harmony with the requirements of the future.

SOME ADVANTAGES OF LIBERAL DESIGN

By B. G. LAMME

COMMENTS UPON THE "TEST OF A 5 000-K W ALTERNATOR"

FRAME OF A 5 000 KW MANHATTAN ALTERNATOR

In Mr. Gaillard's paper on the "Test of a 5 000-kw Alternator" it will be noted that the losses based upon measurements show the measured iron loss to be less than one-third the permissible iron loss fixed by the contract specifications. The measured copper loss is also lower than the contract figure, being less than 60 kw. It may be of interest therefore to note that the iron loss of these machines could be three times as great as the measured loss and still meet the contract conditions. Therefore the margin for errors in the method of testing is so great that ordinary discrepancies, possibly making a difference of 20 to 30 per cent. in the loss, would hardly be noticeable, as there is an available margin of 200 per cent.

The tests on this machine indicate very clearly what can be done by the manufacturer when the conditions of the contract will permit a machine of liberal dimensions. Here is an example of a machine primarily rated at 5 000 kw, but which could be rated at probably 7 000 kw with as much margin as is found on ordinary machines. The liberal capacity of this machine is due, partly, to the fact that a flywheel type of generator was chosen with a very large flywheel capacity. This necessarily required the machine to be of very large dimensions, so that the design electrically and magnetically could be made very liberal, as the dimensions were fixed very largely by mechanical considerations. Therefore, while the purchaser bought a machine of a nominal rating of 5 000 kw and paid a high price per kilowatt on account of the enormous dimensions, in return for this investment he obtained a machine having an abnormal overload capacity. The purchaser, in the case of the Manhattan machines, has therefore obtained a much better machine than he contracted for, and he has since given it a 20 per cent. higher nominal rating. Considering, therefore, the value of the floor space saved, the increased rating permissible, and the higher performance of these machines,

there is no doubt that the investment has been better than if the usual type of generator had been bought.

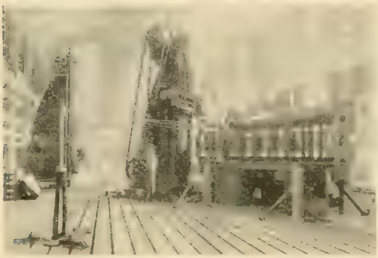
This is a good example of what can be done when liberal proportions are permissible, but unfortunately the manufacturers are often obliged to go to the other extreme and furnish the smallest possible machine which can be made to meet a certain specification. In many cases such a machine will conform to contract conditions, but with a relatively small margin, and if future conditions arise requiring heavy loading of such machines, there will soon arise the necessity of increasing the number of units. In the end, the cost of the plant is greater than if units of more liberal design had been permitted in the first place. As they now stand, the eight 5 000-kw engine-type generators in the Manhattan power house are equal to ten units as ordinarily furnished for contract specifications corresponding to those of the Manhattan company. The purchaser has therefore obtained the equivalent of two additional units in this station.

Mr. Gaillard's paper on the tests on these machines makes but slight reference to the parallel operation which was guaranteed. These machines were guaranteed to run in parallel at all loads specified in the contract. From information at hand, it appears that no condition has yet been found where these machines do not operate well in parallel. They will run together perfectly at no-load, full-load or 100 per cent. overload. They will run in parallel with one-half the engine disconnected, and have been so operated at various times. The angular variation in each revolution is extremely small, as is shown by sighting through the rotating parts of two of the machines when they are running in parallel. An examination of the relative speeds, in this manner, shows that during the operation of paralleling there is apparently but a single swing or kick when the switch is closed, and this is of comparatively small amount. There is no continued oscillation, dying out gradually, as has been noted in some plants. This perfect parallel operation is due, partly, to the heavy dampers on the field poles, and partly to the large fly-wheel capacity, with good engine proportions.

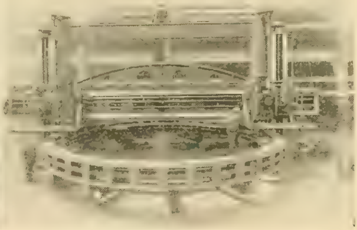
It may be noted in Mr. Gaillard's paper that the short-circuit armature current with normal no-load field current is somewhat over three times full-load armature current. Such proportions give an extremely good regulating machine, but there are accompanying disadvantages.

As a rule, the larger the current the machine can give on short-circuit, the more disastrous will be the effects of such short-circuits. For example, with eight 5 000-kw Manhattan machines in parallel, each machine giving over three times its full-load current on short-circuit, the energy which can be expended at the point of short-circuit will be enormous and the effect will be in the nature of an explosion.

For the operation of rotary converters, where each machine in itself furnishes some regulating element, it is a question whether there is any advantage in having generators with such good inherent regulation. Experience shows that machines which give 1½ times full-load current on short-circuit, will operate rotary converters in practically the same manner as those which



MACHINING THE FRAME OF A 5 000 KW ALTERNATOR



MACHINING THE FIELD OF A 5 000 KW ALTERNATOR

have twice this ratio, and at the same time the effect of a short-circuit on the system will be less destructive. Many cases have been noted where regulations of 10 to 12 per cent. on machines have given just as good results in operation as 5 to 6 per cent. regulations, where the load consists of rotary converters. With compound wound rotaries, the regulation of the generators can be even 15 to 20 per cent. with satisfactory results.

The only consideration of importance in generators having 15 or 20 per cent. regulation would be the parallel operation. If they have ample dampers on their poles and their prime movers have sufficiently uniform rotation, they will operate in parallel perfectly. With turbo generators, these machines operate in parallel almost independently of their regulation, as the turning effort is uniform.

CONSTRUCTION OF THE 5 000-KW. ENGINE-DRIVEN ALTERNATORS

By R. L. WILSON

WHEN the Manhattan Railway power-house was planned, the 5 000-kw generators then ordered were the largest ever attempted, and these, together with those later built for the Subway power-house, still remain in dimensions and weight the largest electrical machines ever constructed. This distinction they bid fair to retain for some time, now that turbine apparatus has taken the field and monopolizes the attention of designing engineers. From the outset the design of these generators was governed by certain fixed conditions, the most important being the speed of the engine and the fly-wheel capacity to be provided in the rotating element of the generator, it having been previously determined to do away with the use of separate engine fly-wheels. These limitations led to the production of a revolving field or wheel 32 ft. in diameter and weighing approximately 332 000 lbs., the major portion of this weight being in the rim. The stationary part, or armature, to surround this field has a height of 42 ft. and a weight of 558 000 lbs.

The mechanical design and actual construction of such huge machines is a serious problem. After mature deliberation, it was decided to build the revolving field as a plate wheel, the rim being supported from the center by plates, instead of spokes or arms. This construction has obviously many advantages, but at first glance it presents a number of disadvantages, and its adoption seemed to cause considerable surprise among engineers, and at the start of installation elicited more or less pessimistic comment and criticism. It has, however, amply justified its originators, and has shown none of the predicted tendencies to vibration, and to run out of true.

The Manhattan machines have 480 slots in the armature, and are wound with three bars per slot. As there are forty poles, the winding is necessarily arranged to give four slots per phase per pole, thus insuring a smooth wave form and adaptation to synchronous operation. The Subway generators have but 360 slots and a correspondingly greater number of bars per slot. The electrical characteristics, however, correspond closely with the earlier units.

In winding, the insulated bars are placed in the slots and held firmly be grooved fiber wedges driven into slots over the top

of the bars. To produce a continuous circuit, the bars are connected on either side of the machine by specially shaped connectors which are insulated in a manner similar to that of the bars, but not to the same extent. The individual groups of three bars are capable of safely withstanding a potential of 40 000 volts to ground, and the various sections of the winding during installation were subjected to a preliminary test of 30 000 volts to ground for several minutes. After the entire completion of the machines ready for operation, the armature coils were given an official breakdown test of 25 000 volts for thirty minutes. The finished winding presents a very attractive appearance, and is essentially adapted to ease in the making of repairs.

The winding of the Subway machines not only differs from the Manhattan in having fewer coils with a greater number of turns per coil, but the shape of the coils is also considerably modified. The individual conductors are insulated substantially in the same manner, but they are roughly of a "U" shape, several of them being assembled and insulated together to form an open coil, which is slipped into the slots from one side of the machine, the ends being then connected, soldered and insulated to complete the coil. This type of winding is not so attractive in appearance as the former and is slightly more difficult to repair, but it is somewhat more rigid and not only reduces the number of soldered connections by half, but also lends itself more readily to being braced against the strains due to accidental short circuits. The insulation upon the external portion of these coils differ from that of the Manhattan winding, in that it consists largely of oiled linen tape laid on with Sterling varnish.

The foregoing extract is taken from the article which appeared in *The Engineering News* on "The Erection of the 5 000 kw Engine-driven Alternators," by R. L. Wilson, by whom the alternators were erected.

VARIOUS KINDS OF EDUCATION*

By WALTER C. KERR

THE world wants men who can do things.

Cornell has always done things and the habit is infectious.

There is a peculiar bull's eye directness about the Cornell motive that counts.

It is not probable that a few thousand young men assembled at random in one place differ materially from a like number assembled elsewhere, except as they are attracted by something that consciously or unconsciously appeals to them.

The older institutions attract students rather better prepared, with more antecedent educational atmosphere, financially more able to pay for advantages, but also a large number who lack serious motives.

Cornell, on the other hand, attracts a very large percentage of men bent on serious missions though not indifferent to the colors that add to the good cheer of nations. On this material Cornell places her stamp of knowledge for action and measures acquirements by results, not by the capacity to contain.

I don't know why anything need be said about education on an occasion like this. If we haven't got enough education we aren't likely to get much more by talking about it, and if we have enough the time might be better spent on something we haven't got. However, as the education we received and the conditions under which we received it underlie the motives of our gathering, it is of some interest to us what trend education is taking, if we are interested in what our sons will get.

"The results of things follow not so much from their state as from their tendency," and so our interest is not so much in the kind of education that is being given at the moment as in the tendencies marked by the changes which determine what it will become.

Cornell has played an active part in the development of education in this country. It started with strong initiative force through men who felt but hardly dared formulate their inclinations towards something which was better than that which had

*Taken from an address at the annual dinner of the Cornell University Alumni at Chicago, April 1, 1905.

been. They were men who reached forward from the limitations which compressed their past to aspirations which they could not quite measure or define.

Nevertheless, in some way, consciously or unconsciously, there evolved from and through these men the power to do things, which though simple in themselves, were far reaching.

I regard as the first of these the declaration that all kinds of education are equal. The democracy of this is so simple as to seem axiomatic, but that it was a departure is shown by the fact that after nearly forty years it is not yet quite universally believed.

The second I believe to be the proper view of the relations between the so-called liberal and utilitarian courses of study.

The third may have been the bold willingness to do the right thing every day and all the time as opportunity offered, without too fixed a goal, but trusting that the results would be the best that right could make. They went as far as they could see and then saw how far they could go. This underlies the pioneer spirit. Men do not know what they are going to make of a new country and its resources, but they plunge in, turn it over and make of it the best they can; always in the spirit of industry and honesty; with that aspiration for betterment which invariably turns to good that which is worthy and turns to naught that which is undesirable.

Thus Cornell started—with no entrammeling traditions; no compressing environment; surrounded only by the four winds of heaven; the courage of her convictions making her superior to criticism.

The result was a new kind of institution. It was called a poor man's college, for reasons we all know. It has since remained a poor man's college, but poor men are not quite so poor as they used to be, and it would be strange if they were, amid all the resources of this great country. Then followed the years of struggle filled with incidents which form the oft-repeated history of the early days. The day came, however, when through the sale of lands, the gifts of many benefactors, and the added talent of an every increasing faculty, we had a well rounded university.

This was the result of influences which for a score of years had, from the rude beginnings on the Ithaca hill, shaped the ends

which have reached deep into other institutions of learning throughout the land.

As a result we have 3 100 students, departmented as follows: Post-graduates, 200; Arts, 700; Law and Medicine, 600; Applied Science (chiefly engineering), 1 600.

Contrast this condition where only one-fourth of the students are in Arts course, with the old academic institutions with an eye to what education should consist of when a large number of intelligent men are left to freely choose what is best adapted to their needs.

The fact that under these conditions so few elect the humanities has often been deplored as the decadence of classical training. I do not think so. It is rather the beginning of a higher development in which the classical will be more effective because not diluted with the dregs of its own failures.

The time was when but one kind of education was known, or at least only one kind of training was called education. Our early colleges were therefore strictly classical, and many are yet.

An educated man was then perforce a classical man and since education led chiefly to the learned professions, the few who in the early days received college training were fairly fitted for their life's work.

Then the so-called blind impulse for the old ideal of general culture led fewer men astray than it does now.

As time went on, institutions grew in size and multiplied in number. Thousands of students took the place of former hundreds.

After a time we began to hear whispers from the practical world, which generally gets things pretty nearly right, that college education was a failure; that men who spent four years and thousands of dollars in academic halls were less fitted for the activities of the world than those who spent these developing years in business or other pursuits.

Educators used everything from argument to ridicule by way of refutation, commonly alleging that men without education were unfitted to judge the product of our institutions.

I think the apparently crude judgment of the world was right and the ineffective theories of many refined educators wrong, and for no uncertain reason.

I think the whole problem is so simple that a few statements can take the place of argument, and especially of contention.

Humanity is composed of all kinds of men, possessing widely different temperaments, tastes, and abilities.

It is well they are not all alike.

Any man will achieve the greatest effectiveness when given the opportunities and training which develop his native powers. Any other training is liable to stunt his growth. His variation, as he progresses in development, should be in the direction in which he tends to vary. This assists in the survival of the fittest; the survival of the unlike, the survival of the effective.

Manifestly there must be as many types of education as there are types of men, and fortunately the number is not so great but that they can be readily supplied within any university.

So long as all men during the process of education were confined to one channel, those whom the channel precisely fitted were greatly benefited. Those for whom the channel was a misfit were injured, for the reason that during the most important formative period of their development their native power to vary was resisted, their minds forced away from their natural trend, and energies which could have been potent for good in certain directions were dwarfed by the compulsory exertion of uninteresting, unproductive effort. This results in that kind of mediocrity which is stagnation.

You can't make anything good of a man except to make him better in that which he is. You can't unmake him and make him over again.

If it be argued that a man must needs have the so-called liberal education in order to be well rounded, following this with the so-called specialized courses, the answer is that he can be forcibly made well rounded like a billiard ball without other characteristic than roundness.

He ought to have corners, and the corners should be left on to dent something.

As to the so-called specialized courses, these are only names. They are no more special than the humanities. Some are scarcely so highly specialized.

The older I get, the more I think that there is no such thing as liberal education, liberal arts, or liberal anything, as distinct from specialized departments of knowledge.

Liberality is the free and equal admission of all.

We have heard too much about knowledge for its own sake versus knowledge for use. All knowledge is for use. All edu-

cation is for action. The engineer uses mechanics and thermodynamics in a certain direct way. The architect uses art and constructive knowledge in a similar way. The lawyer uses his knowledge in a less material way.

The classical or philosophical man uses his acquirements in a different way, but if he does not use them they are useless.

All education is liberal or all is technical according to our definitions, but all is for use.

When it is observed that less than 25 per cent. of the students follow classical pursuits when left free choice, and that over 75 per cent. select professional and industrial education, there is good reason to believe that this is about the proportion in which men's minds are fitted to receive benefit from the acquirement of the respective classes of knowledge and training. I therefore maintain that, instead of a decadence in the humanities they are elevated because their representatives are men whose minds are fitted to take such education and who will therefore conspicuously represent the best possibilities of classical training applied to those to whom it is adapted.

Likewise by processes of natural selection the other departments will have graduates who are conspicuously strong because their best efforts will be put into that which they can do best. I know of nothing pointing more directly to success than that.

It is not necessary to consider the relative merits of the various kinds of education. There is room for all, because there are all kinds of men. It is useless to say I am better than thou, or this is better than that. But one thing is better than everything else, and that is the broad spirit which recognizes that all education is equal, that training is training whenever you find it, knowledge is knowledge, no matter of what it consists, that human effort is human effort, no matter to what it is applied, and when it has singleness of purpose and is resourceful, it is effective.

THE AUTOMATIC SYNCHRONIZER

By NORMAN G. MEADE

THE uncertainty in synchronizing which arises from the hand-throwing of switches is done away with by the automatic synchronizer.

The instrument consists essentially of two solenoids, the upper ends of whose movable cores are flexibly connected to either end of a cross-beam pivoted at its center as an ordinary walking-beam. These solenoids are so connected that the one receives a maximum current at the instant of synchronism and the other receives a minimum current at the same instant. To accomplish this, the right-hand solenoid is connected in the same manner as a synchronizing lamp is connected to synchronize light and the left hand solenoid is connected like a lamp to synchronize dark.

Attached to the shaft of the cross-arm is a small contact finger or clip. This contact device is for closing a circuit through the re-

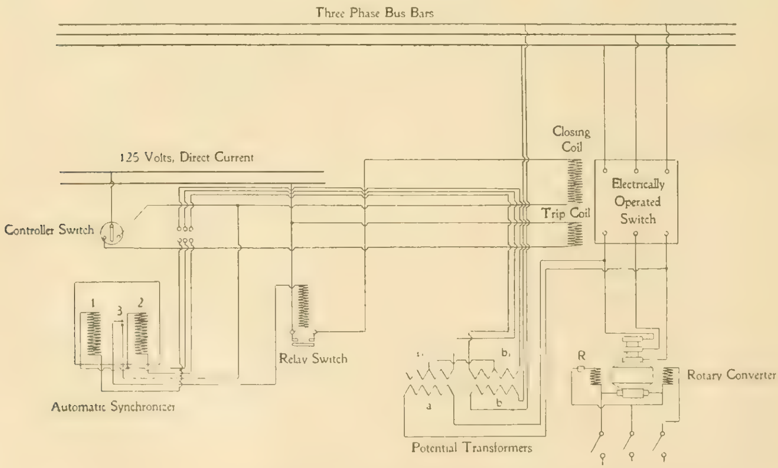


FIG. 1—WIRING DIAGRAM FOR AUTOMATIC SYNCHRONIZING

lay switch which closes the circuit through the closing coil of an electrically operated switch at the proper moment of synchronism. The current for actuating the switch is taken from a source independent of the generators—from the exciter shown in Fig. 1. To the cross-beam is also attached one element of a dash pot. The other element is connected through a system of levers to a disc of insulating material mounted on a short shaft in line

with the pivot of the cross-beam. A small metal segment mounted on the disc is a little longer than the gap between the movable clip and a stationary clip, when the clips are at their minimum distance apart. Mechanical adjustment is made such that this minimum distance point is reached coincident with the point of synchronism. Reference to Fig. 2 will show how this dash-pot action on the disc prevents the movable clip from making contact with the stationary clip when the rocking motion of the cross-beam is too rapid. Be-

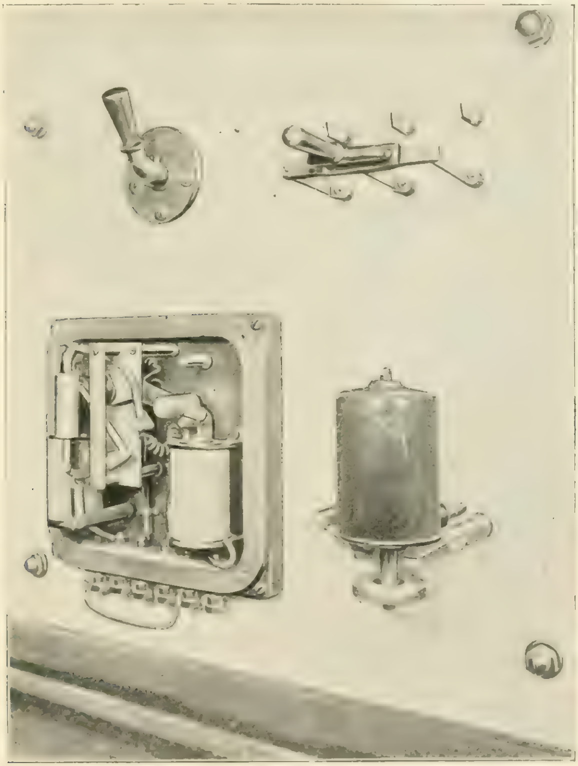


FIG. 2—THE AUTOMATIC SYNCHRONIZER, COVER REMOVED

fore the incoming machine has approached synchronism both of the solenoids are acted upon equally by currents from the synchronizing transformers and the cross-beam will assume a position midway between its two extreme positions. As the point of synchronism nears, the beam will begin to oscillate, following in its movements the variations in the currents. In one solenoid the current

is a maximum while in the other it is a minimum, and vice versa. As soon as the oscillation becomes slow enough, the dash-pot is pulled out to its maximum length with the forward movement of the beam, and the contact piece on the insulating disc remains in the proper position to make the circuit between the moving and the stationary clips.

If the voltage of the incoming machine differs considerably from that of the bus bars to which it is to be connected, the device will not close the contact since the effect of the excessive voltage on the left-hand solenoid is to hold that end of the beam too low at the moment of synchronism. It is thus seen that the incoming machine will not be thrown in, unless the voltages are approximately equal, the machine is in phase, with the line, and the frequency is right.

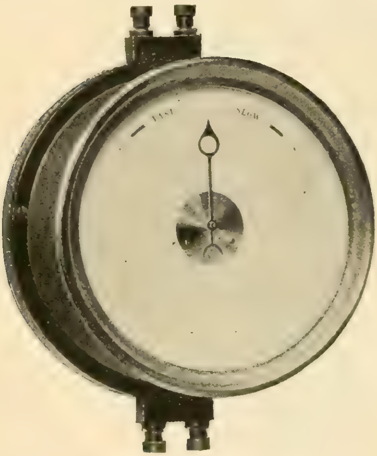


FIG. 3—TYPE A SYNCHROSCOPE

A controlled and relay switch are interposed in the circuit with the synchronizer and the electrically operated switch. By means of the controller switch the main or electrically operated switch may be tripped, but cannot be closed, as the closing coil is normally out of circuit until the synchronizer is in the position assumed at the synchronous operation of the generators or rotary converters, that is, when the solenoid of the relay is energized and the contacts closed. This closes the relay switch circuit and completes the path of the current through the controller and electrically operated switches.

The relay switch is provided with carbon break and relieves the contacts of the synchronizer from excessive currents.

Fig. 1 shows the detailed connection of the automatic synchronizer, controller switch, relay switch, electrically-operated switch, rotary converter, potential transformers and bus bars.

The primary *b* of the potential transformer is connected across the bus bars, and the primary *a* of the other transformer is connected to corresponding terminals of the rotary converter behind the electrically operated switch, that is, between the switch and the

rotary converter. The contacts inside the synchronizer never have to break any current when properly adjusted, and they will last indefinitely. Machines are synchronized by this instrument without the least strain, the ammeters connected to the incoming machines showing hardly any deflection.

For rotary converter work, a simple form of electrically operated switch has been devised to use with the automatic synchronizing system, combining the functions of a switch and an automatic circuit breaker thus omitting the knife switches and fuses. For high voltage work, automatic oil switches are used. As automatic switches require a certain period of time to close, it is necessary that the closing operation begin in advance of the point of synchronism so that the switch will close at the correct time.

This adjustment is easily made to suit any particular form of electrically or pneumatically operated switch. The wiring of the various devices forms a complete interlocking system, preventing the coupling of machines under unfavorable circumstances, and avoiding the possibility of any resulting damage.

A device similar to the one described above, has been used for some time for synchronizing rotary converters in the main station of the Pittsburg, McKeesport & Connellsville Railroad, and has given entire satisfaction.

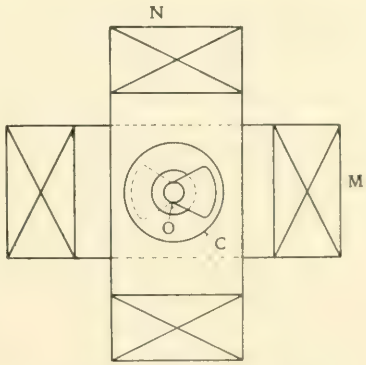


FIG. 4—ARRANGEMENT OF THE COILS IN A TYPE A SYNCHROSCOPE

OTHER SYNCHRONIZING DEVICES

In synchronizing alternating current machines, three things must be indicated in one way or another to the attendant, namely: the phase relation of the two voltages, the relative value of the two voltages and the relative frequency of the two circuits.

The operation was first accomplished by the use of synchronizing lamps and a voltmeter. With this method the speed of the incoming machines, whether fast or slow, can only be determined by trial—by varying the speed and noting the effect on the fluctuating lamps.

The inconvenience of synchronizing with lamps* has led to the development of various types of an instrument known as the synchroscope. Two of these are described in the following:

The type A synchroscope is shown in Fig. 3 and the arrangement of coils in Fig. 4 where *N* and *M* are two coils arranged at right angles to one another and wound so as to give a uniform magnetic field. Through the coil *N* passes a current which is in phase with the voltage of the circuit to which the machine is connected, a non-inductive resistance being placed in series with this coil. Through the coil *M* passes a current which is approximately 90 degrees out of phase with that in coil *N*. An inductive resistance is placed in series with this coil. These two coils with their respective resistances are energized in parallel from the main line. As the current in coil *N* will be a maximum when that in coil *M* is zero, and vice versa, the field produced by these two coils will rotate with a speed which depends upon the frequency of the circuit to which they are connected. A small stationary internal coil *C* has an iron core which is pivoted so that it can rotate and thus bring its axis in line with coil *N* or *M*. This small coil is connected to the incoming machine.

In the direction *OM* the field will be zero when the voltage on the coil *M* is zero, and in the direction *ON* the field will be zero when the voltage on coil *N* is maximum. Thus between these two points a zero field can be found at any time between the maximum and zero of the voltage on the coil *N*.

As the iron within the small coil *C* will be attracted or repelled by the field of the coils *N* and *M*, it will take up a position in which its zero field will occur at the same time as the zero of the rotating field. Thus, if the current in the coil *C* is in phase with the current in the coil *N*, the iron will take up a position with its axis in the line *ON* while if the current in the coil *C* is at quadrature with the current in the coil *N*, the iron will take up a position in the line *OM*. For any phase relation between these two it will take up a corresponding intermediate position between *ON* and *OM*.

The movable iron in the coil *C* will thus shift around to a position which corresponds to the angle between the currents in the coils *N* and *C*, and if a pointer is attached to the iron core and arranged to move over a graduated scale, it will show the

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*See "Synchronizing of Alternating Current Machines." THE ELECTRIC CLUB JOURNAL, Vol. I., p. 679.

difference in degrees between the phases of these two currents.

Should this phase difference continually vary, as will be the case with the two machines running at different speeds, the pointer will continually rotate, and thus show the relative difference in speed. It will thus indicate when the machine is in proper phase relation with the circuit to which it is to be connected.

The non-inductive resistance, which is wound of fine German silver wire and the inductive resistance or choke coil are mounted within the case, making the instrument self-contained. The current taken by this instrument is approximately one-tenth of an ampere, from each circuit.

The type B synchroscope is built on the principle of an induction motor, all the parts being similar in construction to those used upon small motors. It is thus more powerful than the type A synchroscope just described and more energy is required in its operation so that it is inadvisable when not in service to leave it connected to voltage transformers supplying other instruments. If connected to voltage transformers supplying other instruments, it indicates synchronism in the same manner as the type A instrument. A diagrammatic illustration of the principle of operation is given in Fig. 5.

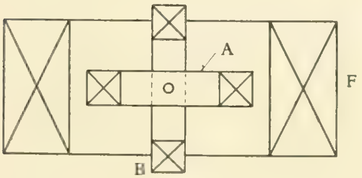


FIG. 5

A stationary coil *F* has suspended within it a coil *A*, free to move about an axis in the planes of both coils and including a diameter of each. If an alternating current be passed through both coils, *F* and *A*, *A* will take up its position with its plane parallel to the plane of *F*. If now the currents in *A* and *F* be reversed with respect to each other, coil *A* will take up a position 180 degrees from its former position. Reversal of the relative directions of currents in *A* and *F* is equivalent to changing their phase relations by 180 degrees, and therefore in practice this change of 180 degrees in phase relation is followed by a corresponding change of 180 degrees in their mechanical relations.

If, instead of reversing the relative direction of currents in *A* and *F*, the change in phase relations between them be made gradually and without disturbing the current strength in either coil, it is evident that when the phase difference between *A* and *F* reaches

90 degrees, the force between *A* and *F* will become zero and the coil *A* will remain in any position in which it is placed. Let a second member of this movable system consist of coil *B*, which is fastened rigidly to coil *A*, with its plane 90 degrees from that of the coil *A*, and the axis of *A* passing through the diameter common to both *A* and *B*.

Further, if a current circulates through *B*, the difference in the physical relation to that in *A* will always be 90 degrees. It is evident under these conditions that when the difference in phase between *A* and *F* is 90 degrees, the movable system will take up such a position that *B* is parallel to *F*, because the force between *A* and *F* is zero and the force between *B* and *F* is a maximum; similarly when the difference in phase between *B* and *F* is 90 degrees, *A* will be parallel to *F*. That is, beginning with a phase difference between *A* and *F* of zero, a phase change of 90 degrees will be followed by a mechanical change in the movable system of 90 degrees, and each successive change of 90 degrees in phase will be followed by a corresponding mechanical change of 90 degrees. For intermediate phase relations it can be proven that under certain conditions the position of equilibrium assumed by the movable element will exactly represent the phase relations. That is, with proper design the mechanical angle between the plane of *F* and that of *B* is always equal to the phase angle between the current flowing in *F* and those in *A* and *B*, respectively.

FIG. 6 — SYNCHROSCOPE WITH 36-INCH FACE, MOUNTED ON A PEDESTAL

As commercially constructed, coil *F* consists of a small laminated iron field provided with a winding whose terminals are connected with the lower binding posts. The coils *A* and *B* are windings practically 90 degrees apart on a laminated iron armature pivoted between the poles of the above field. These two windings are joined and a tap from the junction is brought out through two small slip rings, one of which is connected to the remaining top binding post, through a non-inductive resistance and the other to the

same binding post—through an inductive resistance. A light aluminum hand attached to the armature shaft marks the position assumed by the armature.

Fig. 6 shows a synchronizer having a 36-inch face and mounted on a pedestal, so as to be visible from any point in the engine room.

ELECTRIC RAILWAY BRAKING

PART VII

By E. H. DEWSON

MOTOR DRIVEN COMPRESSORS

MOTOR driven compressors for supplying air for operating the brakes of electric cars were first built, in any considerable number, for the Intramural Railway at the World's Columbian Exposition held at Chicago in 1893. These compressors had a single oscillating cylinder with a double acting piston, the crank shaft being geared to a series wound motor of the railway type. Since that time many designs, including two single acting cylinders, worm gearing, direct connection of the armature and the pump shafts and rotary compressors, have been tried.

The worm gearing admits of a high ratio of reduction, consequently a high speed light weight motor may be used; also it is quiet in operation and free from vibration. A high efficiency of the gearing is difficult to obtain and still more difficult to maintain. The end thrust of the worm shaft is particularly objectionable in the case of an air compressor on account of the extreme fluctuation of load which occurs during each revolution of the crank shaft.

The direct connection of the motor and compressors, while eliminating the expense and noise of the gearing, involves a high rate of reciprocation of the piston, or a very low speed motor of excessive weight. An efficient and satisfactory valve for a compressor of a capacity of ten or more cubic feet per minute, and to operate over 300 times per minute, has not yet been designed. Moreover the loss due to the clearance space between the valves and the piston increases directly as the number of strokes per minute.

The direct connected rotary is the ideal form of compressor for electric motor drive. All noise of gearing and valves and knocking of slack connections are eliminated, and a

practically uniform torque is obtained. The nicety of construction required for successful operation makes it impracticable to place this machine under the care of the ordinary car barn mechanic.

The type of compressor which, up to the present, has most satisfactorily filled the requirements of electric traction service has two single acting cylinders located side by side and operated from

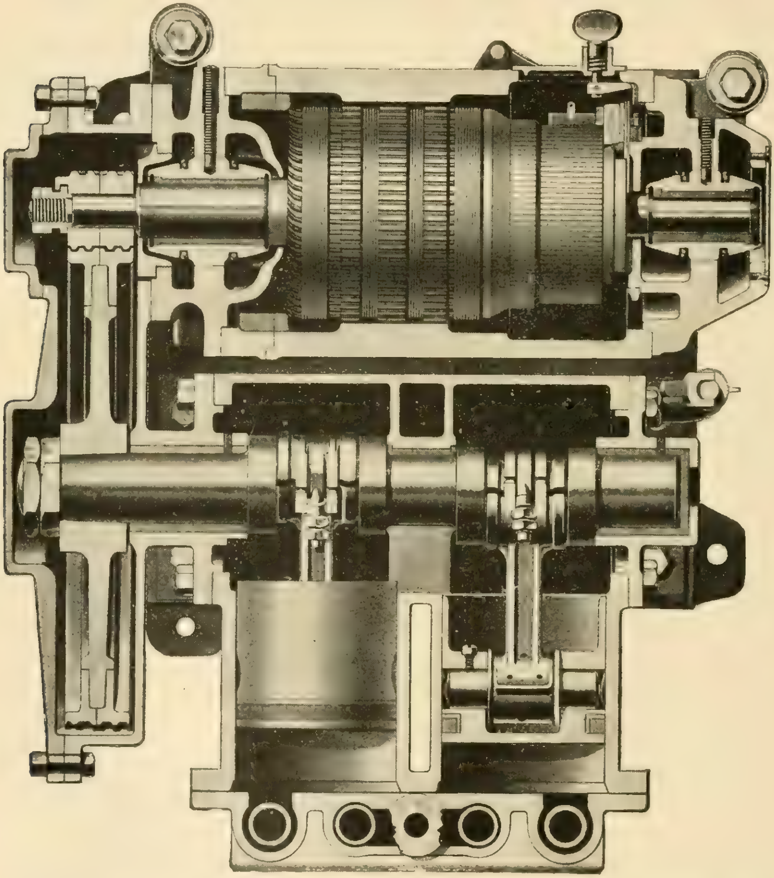


FIG. 21—HORIZONTAL SECTION THROUGH A COMPRESSOR WITH MOTOR AT SIDE OF CRANK CASE

the same crank shaft. The shaft is driven through herring-bone gears by a motor which is located either at the side or above the crank case. When located at the side of the crank case the motor is self contained and may be removed for repairs and testing, and another substituted. Also access to the interior of the crank case is permitted by simply removing the cover. With the motor located

above and forming a cover for the crank case as shown in Fig. 26, a saving in weight is effected, but at a sacrifice of convenience of access to the crank case. Fig. 21 shows a partial horizontal section of a compressor with self contained motor. In Fig. 22 this same compressor is shown with a section through the valve chambers, located in the cylinder head. As indicated by the arrows the air is drawn through two perforated screens with a layer of curled hair interposed to prevent dust from passing into the interior of the compressor. From the suction chamber above the

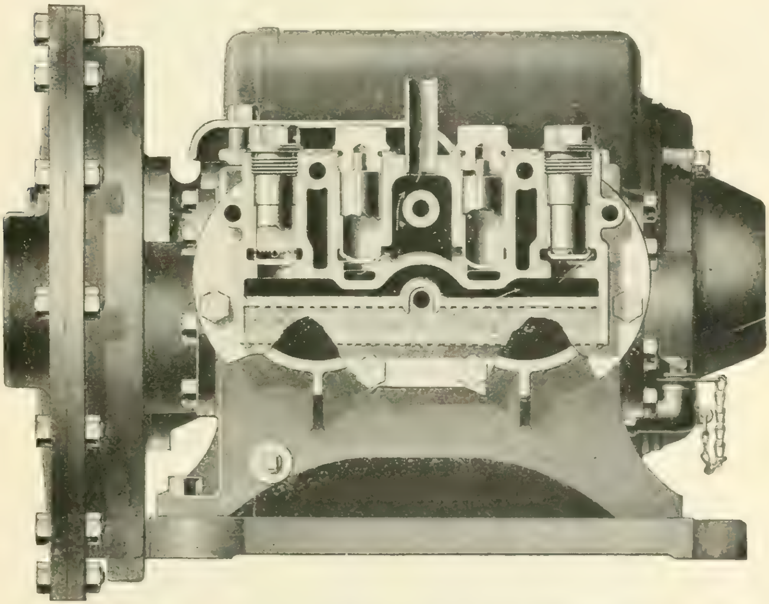


FIG. 22—VERTICAL SECTION THROUGH THE VALVE CHAMBERS OF THE COMPRESSOR SHOWN IN FIG. 21

screens the air passes into one or the other of the cylinders through its suction port, located at the extreme right or left. It is forced from the cylinder through the discharge port into the discharge pipe. From Fig. 23 it will be noted that this form of compressor is completely enclosed, as is the practice with railway motors which operate under the same conditions of exposure to dust and splashing water. This illustration also shows the standard method of suspending this compressor from the car body. To remove the compressor it is only necessary to disconnect the wiring and piping, and take out the keys in the four ends of the cradle, after

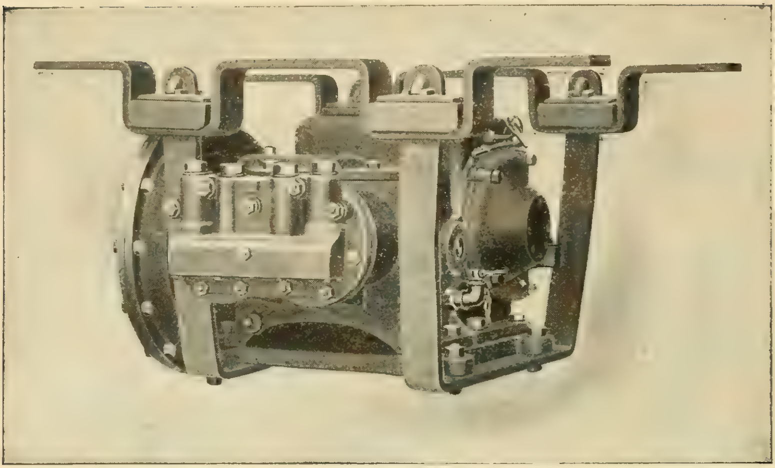


FIG. 23—RAIN AND DUST-PROOF COMPRESSOR WITH CRADLE FOR SUSPENSION UNDER A CAR

having raised the compressor about half an inch. There are no nuts or bolts to be taken out.

In Fig. 24 is shown a compressor of the other design. Its motor is of open construction and for protection a box must be pro-

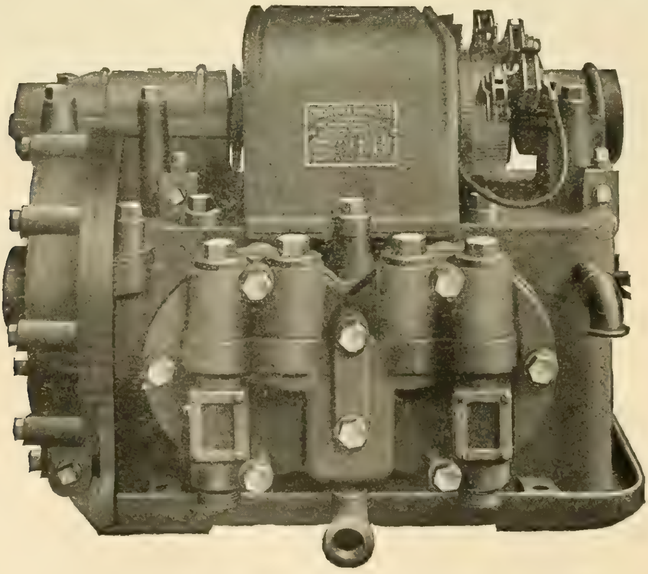


FIG. 24—MOTOR-DRIVEN COMPRESSOR WITH MOTOR ABOVE CRANK CASE

vided which makes the total weight per unit of output practically the same for these two forms of compressors. In Fig. 25 the compressor is shown in its box and cradle, as it is hung under the car. Either of the four sides may be removed, or the entire box can be slid off the base, provided the compressor is located far enough away from the balance of the apparatus under the car.

The lubrication of both designs of compressors is automatic. The crank case is filled to the level of the oil orifice

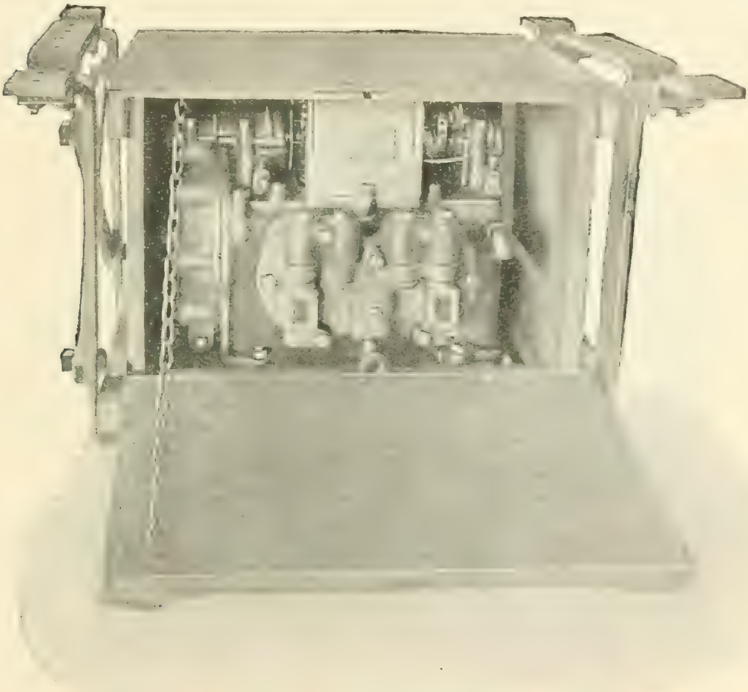


FIG. 25—ENCLOSING BOX AND SUPPORTING CRADLE FOR COMPRESSOR WITH MOTOR ABOVE CRANK CASE

and the cranks, dipping into the oil, throw it onto the parts requiring lubrication. This oil level extends to the gear case for the lubrication of the gears and the pinion end bearing of the motor also receives oil from this source. The commutator end bearing has a separate oil well. Both bearings are provided with oil rings.

For air brake service this type of compressor is built in four sizes of rated capacities, based upon piston displacement, ranging from ten to fifty cubic feet of free air per minute. For a given

brake service such a size of compressor should be selected that, when new and running one third of the time or less, will supply the normal amount of air required. When its efficiency has fallen off, due to a long period of service, this same compressor will have to run about half the time to supply the same amount of air. Under these conditions should an emergency arise, such as a leak or derangement of some part of the apparatus, the compressor would still be able to supply the requisite amount of air, by running continuously for the balance of the trip. Unlike a steam driven compressor the capacity of an electrically driven compressor cannot be increased by

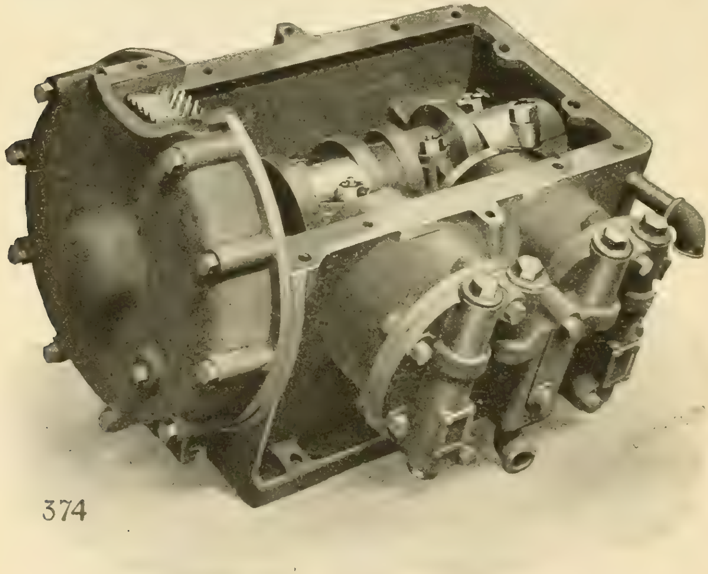


FIG. 26—COMPRESSOR OF WHICH THE MOTOR FORMS THE CRANK CASE COVER

simply opening the throttle wider. Consequently, in order to keep the weight down and to decrease the cost, these compressors are not made for continuous operation against their normal pressure of 75 to 100 pounds per square inch. By designing them for intermittent service aggregating 50 per cent. of each hour, a lighter motor working normally with a 20 per cent. overload may be used, and the temperature rise be kept so far within the safe limit that an occasional run of an hour continuously will produce no injury. When this type of compressor is to be run continuously it must be water jacketed and the capacity of the motor correspondingly increased.

The commercial efficiency of these motors should range from not less than 75 per cent. for the smaller size to 85 per cent. or better for the larger sizes. The cylinder efficiency, or the ratio of the volume of free air actually delivered, to the volume swept through by the pistons in the same period, should not be less than 70 per cent. for the smallest compressor, or 85 per cent. for the largest, these tests to be made when the compressor is cold, the piston packing well seated, and no lost motion in the bearings. These efficiencies will decrease as the compressors become heated or worn in their bearings, but are a reasonable standard for compressors in first class condition.

In small motor-driven compressors just as they come from the manufacturers, a considerable proportion of the electrical input may be consumed in mechanical friction due to the close fitting of the various parts. After the compressor has been in service a little while, if the motor is efficient, the design of the compressor good, and the valves and packing tight, its output should be the maximum attainable with this type. When working against 90 pounds pressure, 275 cubic feet of free air per kilowatt hour of electrical input is a good output for intermittent operation, but to attain this it is necessary to keep the piston clearance at a minimum and the valves tight.

The enclosing of a compressor in a box, through surrounding it with warm air and protecting it from the cooling effect of the draft created by the moving car, decreases its efficiency about 25 per cent. When boxed in, the compressor cannot be so readily inspected, but its external surfaces remain cleaner. This great and continuous loss in efficiency is however a high price to pay for a cleanliness, which, with the enclosed type, may be obtained in a few minutes with a jet of water.

MODERN PRACTICE IN SWITCHBOARD DESIGN

PART V

By H. W. PECK

SWITCHBOARDS FOR ALTERNATORS

THERE are two general reasons why the switchboard equipment for alternating-current apparatus is different from that for direct-current apparatus. First, the inherent characteristics of the machines are in several respects different. Second, the commercial output and the voltage of commercial alternating-current apparatus reach much higher values than those of direct-current apparatus. The first reason requires only a different method of using instruments, switches, meters, etc. The second requires different instruments for accomplishing practically the same results, oil circuit breakers instead of knife switches, transformers in connection with meters, etc.

Alternators are single-phase, two-phase or three-phase, requiring respectively two, four or three main leads. They receive the current for their field windings from a direct-current generator which must always be provided for in an alternating-current equipment of generators or synchronous motors. Some alternators also have a second, so-called composite winding which corresponds to the series field winding of a direct-current generator. The current for this winding is obtained from the secondary of a series transformer built within the armature of the alternator and rectified by a special commutator at the end of the shaft. This current is proportional to the load on the alternator and automatically regulates the voltage at the terminals of the machine.

Before connecting two alternators in parallel it is necessary to see not only that they are of the same voltage but also that the corresponding leads are in the same position in the electrical cycle through which they move, that is, to synchronize them. After it has once been determined that the connections to the paralleling switch are correct for all phases at the same time, it is only necessary to test the condition of synchronism on one phase. The simplest way to synchronize is to connect lamps across the corresponding terminals of the switch, at first across each pole, later any two are sufficient. If then the machines are not in phase, current will flow through the lamps and they will light up. If the machines are in phase the terminals of each pole of the

switch will be at the same potential and no current will flow through the lamps. With this condition obtaining the switch may be closed and the alternators will continue to run in parallel unless thrown out of step by some accident or purposely disconnected. Some engineers prefer to make the connections so that the lamps are bright when the alternators are in synchronism. The reason for this is that the eye can detect a much smaller variation from normal than from zero voltage. As the operator usually estimates the instant of synchronism from the interval of pulsation rather than from the actual brightness of the lamp and as this is easier on the eyes, the connections for synchronising dark are the more usual. That the lamps may be

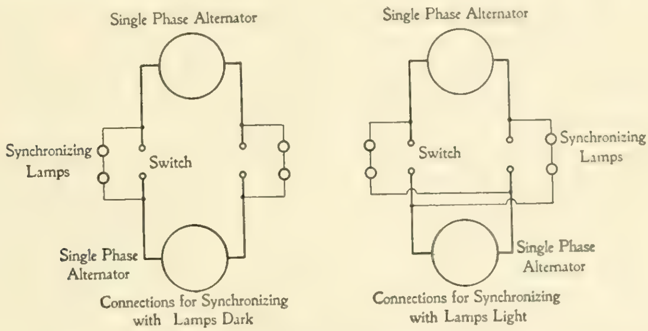


FIG. 16—CONNECTIONS FOR SYNCHRONIZING A SINGE-PHASE ALTERNATOR, WITH LAMPS

bright to indicate synchronism, they are connected across the poles as well as the terminals of the switch. Figure 16 shows the connections for synchronizing two single-phase alternators, both light and dark.

A lagging current in the armature of an alternator has a magnetizing effect which opposes that of the field coils. Conversely, a leading current induces a magnetic flux in the same direction as that set up by the field coils. If the field of one generator be more highly excited than that of another running in parallel with it, the current will lag in the armature of the first, will lead in the armature of the second, and the reactive effect of both will be such as to automatically equalize the resultant field strengths of the two alternators and to deliver power at a pressure between those due to the field excitation of the two machines. For satisfactory operation of alternators in parallel, therefore, it is important to have the field excitation of all the same. Unless

each alternator be provided with its own exciter it is usual to regulate them for the highest power-factor with the separate field rheostats and then to regulate the station voltage by regulating the exciter voltage.

If a power-factor meter is provided with the generators the power-factor obtained with any position of the rheostat arm could be read directly and the arm turned to obtain equal values for all of the machines. If no power-factor meter be provided and the load is steady each generator can be tested for maximum power-factor by noting the effect on the line ammeter of slowly cutting out the field rheostat. If the field is under excited and the machine has a leading power-factor, the current will decrease

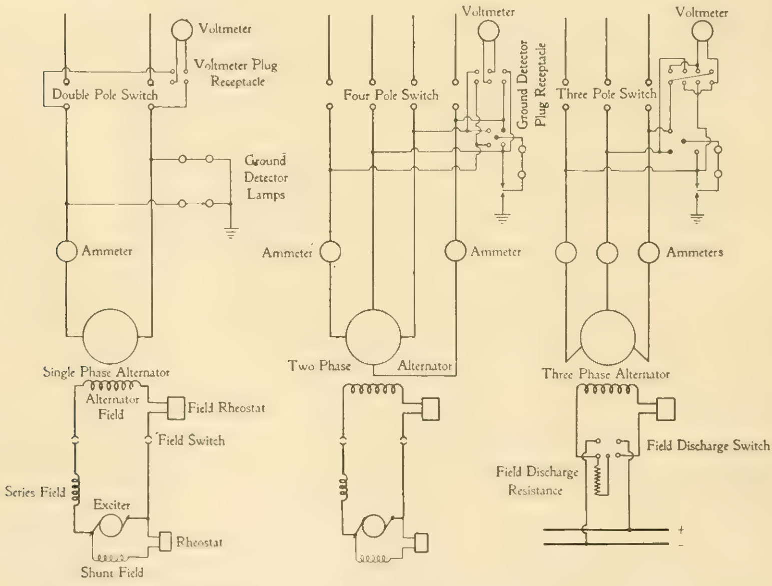


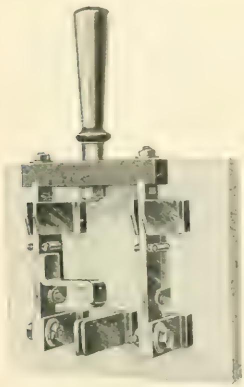
FIG. 17—CONNECTIONS FOR A SINGLE-PHASE, A TWO-PHASE, AND A THREE-PHASE ALTERNATOR

as the field is strengthened; otherwise, it will increase. As minimum current with a given load indicates maximum power-factor, the rheostat should be cut out only to the point where the line current ceases to fall.

The inductance of the armature of an alternator is much greater than that of a direct-current machine, so that the overload current which it will give is much less, being on short-circuit only two and a half or three times the normal load. It is there-

fore usually considered unnecessary to provide automatic overload protection for an alternator.

Fig. 17 shows the connections for a single-phase, a two-phase and a three-phase generator. These have two-pole, four-pole and three-pole line switches, one, two and three ammeters, and four point, six point and eight point voltmeter plug receptacles, respectively. The exciting circuit is the same for all machines consisting of an exciter with its own field rheostat, two single-pole or one double-pole switch, and a rheostat for each alternator field. No automatic protection is supplied either in the main or exciter current. The reason for the former has been given above. The latter is approved because it is believed that the chances for trouble are greater through the accidental opening of the exciter circuits than through the overloading or the burning up of the exciter. The exciter wiring is all in the station where it can be installed most carefully and attended to properly and is therefore very reliable. With the three-phase generators, a double-pole field discharge switch is shown to illustrate the use of this type of switch. It would be equally applicable to either of the other diagrams and is used whenever the exciter is not direct connected to the alternator. This switch is a standard double-pole, quick-break knife switch with an extra contact arm on one blade. This arm reaches the middle jaw of the switch before the quick-break contact opens and closes the alternator field circuit through a resistance of approximately four times that of the field. This prevents the sudden rise in potential in the field windings which would result from opening such an inductive circuit and which would be liable to break down the insulation of the field winding.



FIELD DISCHARGE SWITCH

Ground detector lamps are shown direct connected to the single-phase circuit as in direct-current practice. This arrangement could likewise be used with the two-phase and three-phase systems, but as the underwriters' rules do not require automatic indication of a ground on alternating current circuits, it is more usual to use only one set of lamps, a multi-point plug receptacle and a two-point plug to make tests for ground. This arrange-

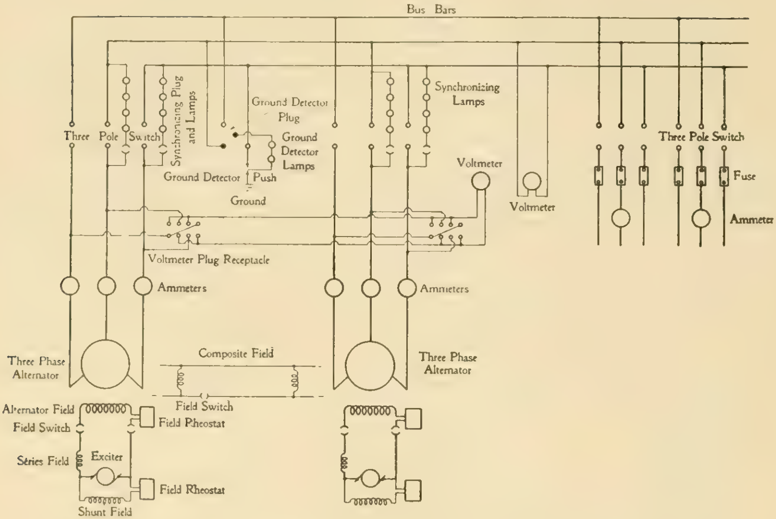


FIG. 18—SWITCHBOARD CONNECTIONS FOR TWO THREE-PHASE, 220-VOLT, ALTERNATORS AND TWO FEEDERS

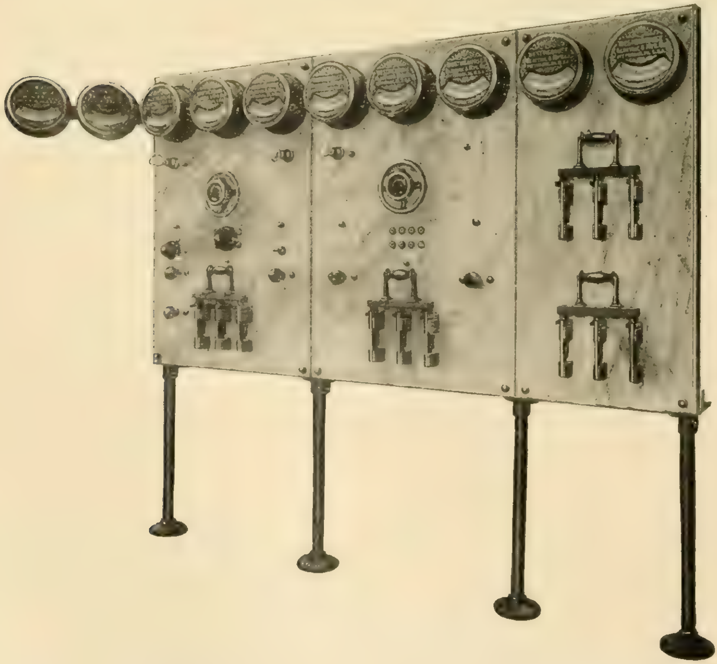


FIG. 19—SWITCHBOARD FOR TWO THREE-PHASE 220-VOLT ALTERNATORS AND TWO FEEDERS

ment is shown on the two-phase and three-phase diagrams. With the voltmeter plug receptacles, a four-point plug is used as it is often necessary to keep the circuits to be measured by the same voltmeter entirely separate. The plug makes contact between two

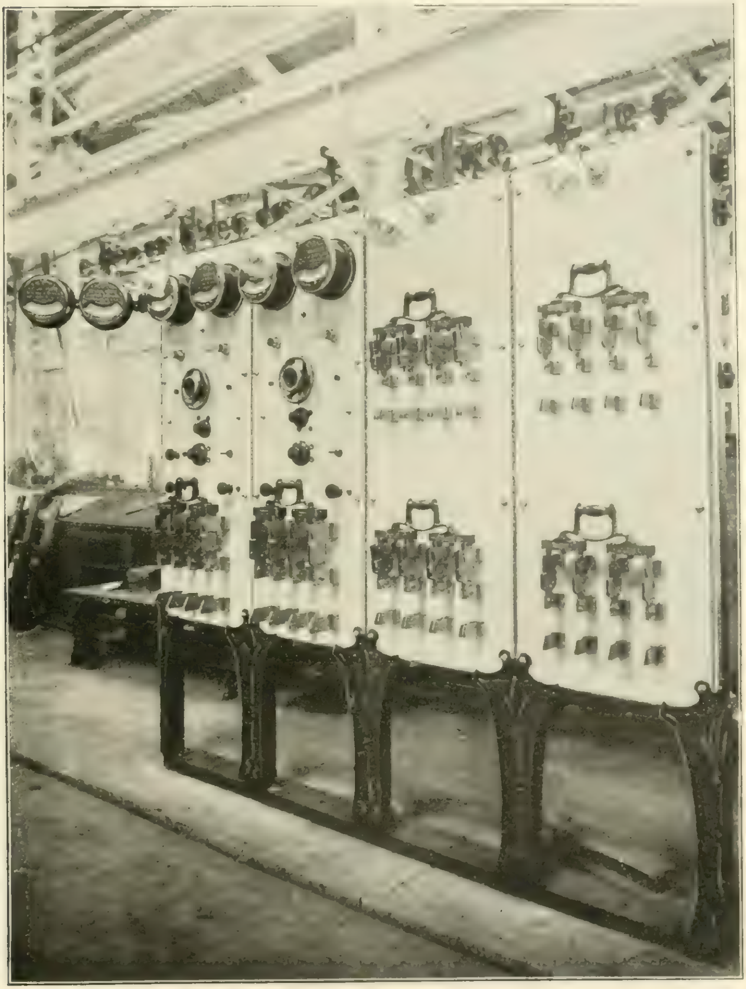


FIG. 20—A TWO-PHASE SWITCHBOARD FOR LARGE UNITS

horizontally adjacent receptacles in both upper and lower row. It is provided with a fuse enclosed within the plug which will protect it from short-circuit due to accident or wrong connec-

tion. The spacing is such that the plug cannot be inserted to make a vertical connection.

Fig. 18 shows the connections and Fig. 19 shows the switchboard for two, three-phase 220-volt alternators and two feeders.

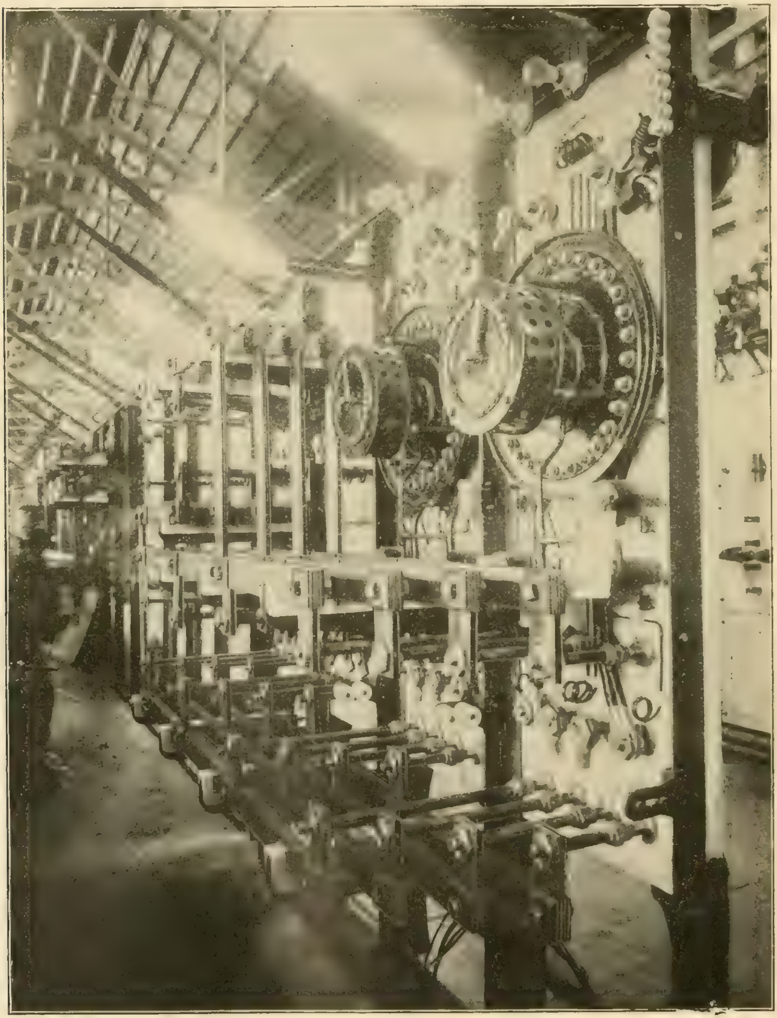


FIG. 21—REAR VIEW OF A TWO-PHASE SWITCHBOARD FOR LARGE UNITS

The connections for paralleling the composite fields of the alternators and for synchronizing the two alternators are shown in addition to the generator equipment shown in Fig. 17. The

feeder circuits are provided with enclosed fuses so that trouble on one feeder will not disturb the rest of the system. If the load on the feeder circuits is balanced, one ammeter is sufficient for each circuit.

Fig. 19 shows that this type of switchboard is similar in construction to the small direct-current switchboard shown in Fig. 6, Vol. 2, p. 42. The three ammeters are mounted at the top of each generator panel. Concentric handwheels are provided for the control of the main and the exciter field rheostats, the smaller wheel being for the exciter. One four-point plug is sufficient for the eight-point receptacles in each panel. A three-pole line switch, two single-pole field switches of the plug type, a synchronizing lamp and two synchronizing plug switches complete the equipment of the second panel. Upon the first panel there is in addition a three-phase ground-detector receptacle and plug, a ground-detector lamp, a ground-detector push button, and a plug switch for connecting the composite field windings in parallel. Additional lamps, required in synchronizing and for the ground detector are mounted at the back of the board, out of the way. The feeder panel contains only the two line switches and the ammeters on the front, the fuses being mounted at the rear. The two voltmeters are conveniently mounted on a swinging bracket at the end of the board. This type of board is limited by its light construction, to small installations. Figs. 20 and 21 show a board of the heavier construction, but of the same general design.

An indication of the tendency of the times can best be obtained by a careful study of the present-day conditions and a glance at the older practice. Within the last ten years many special machines have become standard, and there are now many machines for the work for which there were formerly only the lathe, planer and drill press; so that the machine shop of to-day does not resemble the machine shop of ten years ago, and it is very safe to assume that the shop of ten years hence will be very unlike the present. The change now going on affects the security of investment, the reputation of managers and the trade of machinists.—*James Harkness, in "Evolution of the Machine Shop."*

FACTORY TESTING OF ELECTRICAL MACHINERY—XVI

By R. E. WORKMAN

INDUCTION MOTORS*

THE element of the induction motor which receives the current from the circuit is termed the primary, and the element which receives current by induction from the primary is termed the secondary.

In modern types of induction motors the primary is usually the stationary part, and the secondary rotates.

The windings of both the primary and the secondary are distributed in slots uniformly spaced about the peripheries. The primary winding is usually made of formed coils, each of several turns of wire, insulated and placed in the slots in a manner quite similar to that employed in general types of apparatus, both alternating and direct current. In a two-phase motor there are two separate circuits in the primary winding. In a three-phase motor there are three separate circuits (six free ends) to the winding. Three of these ends are usually connected together inside the frame, thus making a star connection. The other three ends form the motor terminals.

The secondary winding may be made of formed coils or of solid copper bars, one per slot, short-circuited at each end by heavy metallic rings. Coil-wound secondaries are usually three-phase, having their terminals attached to three slip rings. If these slip rings be short-circuited or closed through a resistance, a secondary current will flow and a corresponding torque will be developed in the secondary. With the secondary open, no torque will be developed.

The bar-wound secondary, commonly referred to as having a squirrel-cage winding, is permanently short-circuited at every possible point and therefore has a torque developed in it whenever there is a rotating field in the primary.

The speed of the rotating field in revolutions per minute is equal to the alternations of the supply circuit divided by the number of poles. This speed is known as the synchronous speed

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*For a description of the construction and operation of induction motors see "The Polyphase Induction Motor," by Mr. B. G. Lamme, THE ELECTRIC CLUB JOURNAL, Vol. I., p. 431, 503, 597; also "Application of Alternating-Current Diagrams," Vol. I., p. 606.

and is the limiting speed to which the rotating part approximates under no-load conditions. When the motor is running near synchronism, the torque developed is proportional to the slip or difference between the synchronous speed and the actual speed.

EXPERIMENTAL TESTING

EQUIPMENT. For the convenient and rapid testing of induction motors the power board should contain the various combinations of the different phases, voltages, and frequencies found

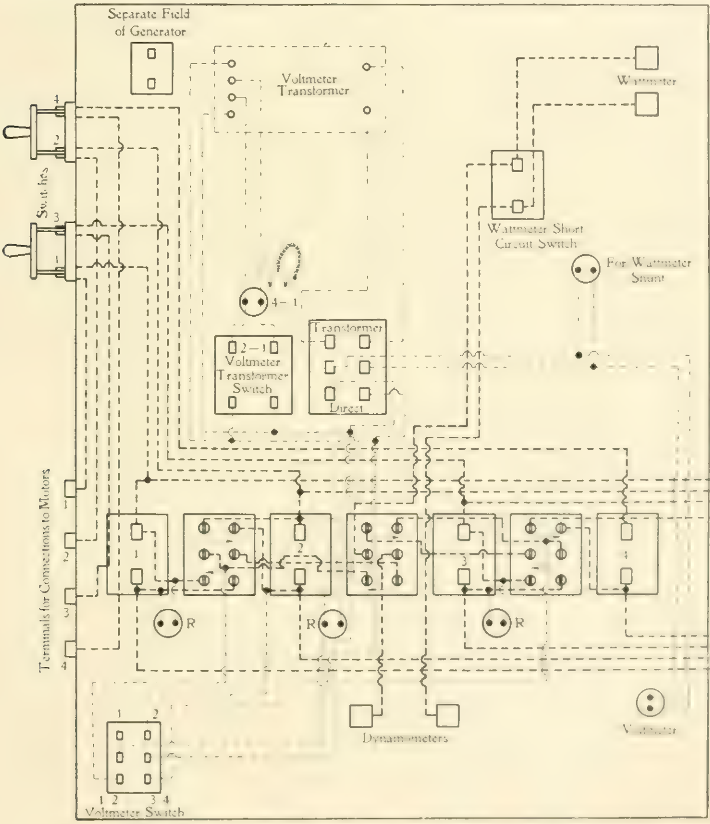


FIG. 74—TABLE FOR TESTING SMALL INDUCTION MOTORS

in practice. To obtain different frequencies, it is necessary to have a different generator for each or some ready means of driving a given generator at different speeds.

Nearly all of the voltage and phase combinations can be made from transformers having specially provided taps for

two phase-three phase connections. A generator having an arrangement for connecting its armature either two-phase or three-phase is very convenient and at times will save considerable transformer capacity. Phase changing transformers are most conveniently made with a one to one ratio.

TABLES. For the testing of machines above 100 hp the table used is the same as that used for alternating-current generators. (See Fig. 56, Vol. I., p. 616). For testing the smaller machines, it is more convenient to use a stationary table, the motors being brought to it. This table, shown in Fig. 74, is very similar to the table used for the large machines. The arrangements for switching the dynamometer, wattmeter and voltmeter from phase to phase are exactly the same. A voltmeter transformer is connected as shown, with a switch and a plug for connecting the two halves of its high-tension side in parallel to give the low ratio, or in series to give the high ratio. A two-to-one, four-to-one transformer is generally used, though any transformer may be readily put in. When the small double-pole single-throw switch is thrown in, the ratio of the transformer is two-to-one; when this switch is open and the short-circuiting plug is put into the socket shown, the ratio of the transformer is four-to-one. A double-pole double-throw switch is shown for connecting the voltmeter either direct to the line or through the transformer.

The rheostats in the field of the 60-cycle generator are conveniently located under this table. The generator field may be broken in an emergency by opening the generator field switch shown on the table.

When measuring small currents, where the inductance of the dynamometer and wattmeter coils would unbalance the phases, compensating inductance coils are inserted in the phases not connected to the dynamometer and wattmeter. For instance, if phase 1 is being measured on a three-phase circuit, an inductance coil will be connected in series in phase 2 and one in phase 3. Receptacles *R* are connected across the switches 1, 2 and 3, and thus inductance coils, which are each provided with plug terminals, can be readily inserted in the phases not being measured, by putting the plug in a receptacle and opening the corresponding switch.

POWER SOURCES. The testing floor of the Electric Company is equipped with three sources of alternating-current power. A 400-kw alternator is belt-driven by a 500-volt, direct-

current motor. The generator has 14 poles and by changing the pulley combination it may be operated at any frequency from 16 2/3 to 66 2/3 cycles. It has four collector rings and may be operated either two-phase or three-phase. Inside the armature spider are two double connectors which when connected toward the collector end give the three-phase connection, and when connected toward the pulley end give the two-phase connection. The field is excited from a 110-volt circuit and the machine will generate about 500 volts on a full field when running at 60 cycles.

A 180-kw generator is belt-driven by a 500-volt, direct-current motor. The generator has 14 poles and is operated at 60 cycles. A small direct-current booster driven by the same motor may be used to boost the motor voltage up or down, thereby obtaining a range of frequency from 50 to 66 2/3 cycles, which may be used for testing small machines, but this is not a stable combination to use for experimental testing where very accurate speeds are desired, unless the motor tested is very small—five to ten horsepower.

A two-phase, 220-volt, 25-cycle circuit from the power house

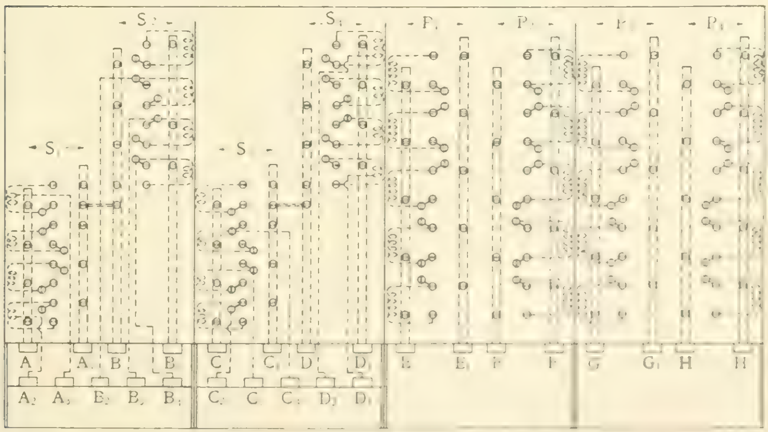


FIG. 75—A 150 KW TRANSFORMER SWITCHBOARD GIVING RATIOS BETWEEN TWO-TO-ONE AND TEN-TO-ONE BY SINGLE POLE SWITCHES

is located on the induction motor test-board. The voltage and frequency of this circuit is sufficiently close and steady for all commercial purposes. When extreme accuracy is desired, the 400-kw plant is used.

TRANSFORMERS. The transformers at the disposal of the testing department are:

Two 200-kw, 10 000-volt transformers (portable), with multi-voltage taps.

Four 150-kw, 2 000-volt transformers, with multi-voltage taps. taps.

Four 50-kw, 200-volt transformers, one-to-one ratio.

Four $32\frac{1}{2}$-kw, 200-volt transformers, one-to-one ratio.

The four 150-kw transformers are connected to the switchboard shown in Fig. 75. It will be seen that the primary and secondary windings of each transformer are divided into a number of sections which can be grouped either in series or in paral-

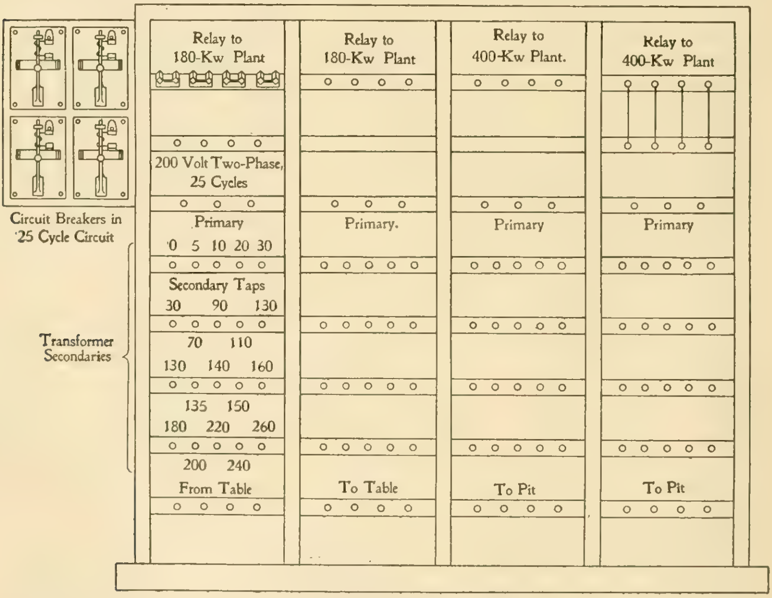


FIG. 76—INDUCTION MOTOR POWER BOARD CONTAINING RELAYS TO THE VARIOUS SOURCES OF POWER AND FOUR ONE-TO-ONE TRANSFORMERS

lel, varying the ratio from two-to-one to ten-to-one. The transformers, when used on a three-phase circuit, may be connected either in star, delta or V, whichever is most suitable, or the primaries may be connected one way while the secondaries are connected another. Thus if it is desired to obtain 2 000 volts, three-phase, from 400 volts three-phase, the three 400-volt lines are connected to *A*, *B* and *C*, and A_1B, B_1C and C_1A are each connected by means of short lengths of cable. The high tension

lines are taken from *E, F* and *G*; E_1F, F_1G and G_1E being each connected by means of short lengths of cable. The two halves of S_1, S_2 and S_3 are connected in parallel and all the sections of P_1, P_2 and P_3 are connected in series.

Care must be taken not to short-circuit a section of the transformer windings in switching them to the bus bars; it will be seen that it is quite possible to do this, and the effect of such a mistake may result in burning out the section in the transformer.

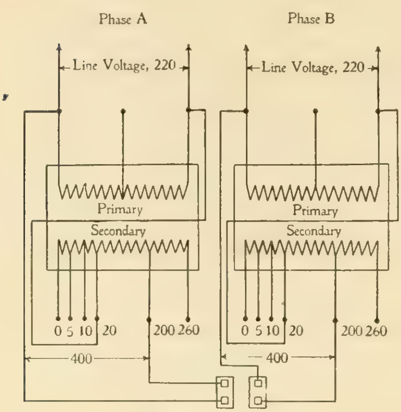
The lower terminals shown in the figure are for the two phase-three phase connection, but, as these transformers are generally used with the 400-kw generator, which can be connected to give two or three-phase currents, these transformer connections are not often used.

Fig. 76 is a diagrammatic sketch of the 50-kw transformer board. The circuit breakers on the left are in the 25-cycle circuit. The two relays at the left extended to the 32½-kw transformer board and are used to connect the 50-kw transformers to the 180-kw generator. The two relays to the right extend to the distribution board of the 400-kw generator. The middle terminals on the primaries of the transformers are taps from the middle points of their primary windings. The secondary taps are brought out from such parts of the windings as to give, at no-load, the voltages indicated in the figure, with 220 volts on the primaries. The terminals marked *To Table* are used for connecting a motor to the power through the test-table. Lengths of cable with metal plugs at their ends are used for making connections between different parts of the board. Each terminal on the board is provided with a double spring jack.

SPRING JACK AND PLUG REPRESENTED IN FIG. 76

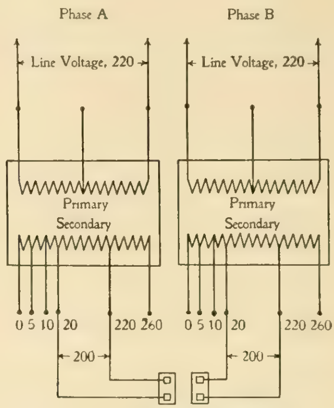
Combinations for Various Voltages—Figs. 77, 78 and 79 show the connections for running a 200, 400 and 500 volt, two-phase motor, respectively. These diagrams are self-explanatory and will suggest the connections for other voltages which are sometimes met with.

For running three-phase motors, the two phase-three phase connection of the transformer is generally most convenient. In doing this it must be remembered that if the two-phase circuit is



Terminal Block of a Two-Phase 400-Volt Motor

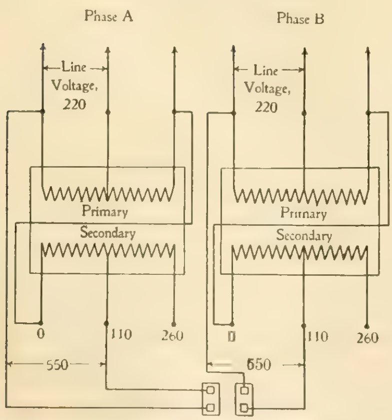
FIG. 78



Terminal Block of a Two-Phase 200-Volt Motor

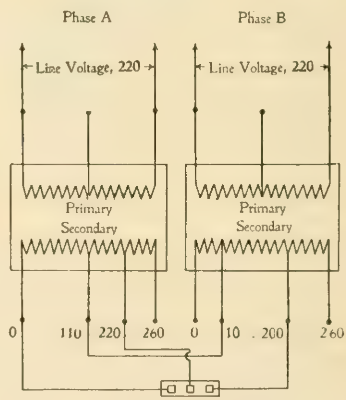
FIG. 77

also carrying a rotary converter load, or is supplied from a generator having a continuous or interconnected winding, no cross connections can be made directly between the phases to convert



Terminal Block of a Two Phase 550-Volt Motor

FIG. 79



Terminal Block of a Three-Phase 200-Volt Motor

FIG. 80

from two-phase to three-phase by means of auto-transformers. This difficulty may be overcome by using transformers between the power and the auto-transformers used to convert to three-

phase, the secondaries of these transformers giving the required independent two-phase circuits as shown in Fig. 81.

Figs. 80 and 81 show the connections for running a 200 and a 400-volt, three phase motor, respectively. The connections for other voltages will readily suggest themselves.

The two phase-three phase connection as shown in Figs. 80 and 81 may be used over considerable range of voltage by alternating the excitation. For example, if the right hand two transformers, Fig. 81, be excited from 0 and 200 instead of 0 and 220, the voltage at the motor terminals will be 400 instead of 440, but the three phase relation still holds.

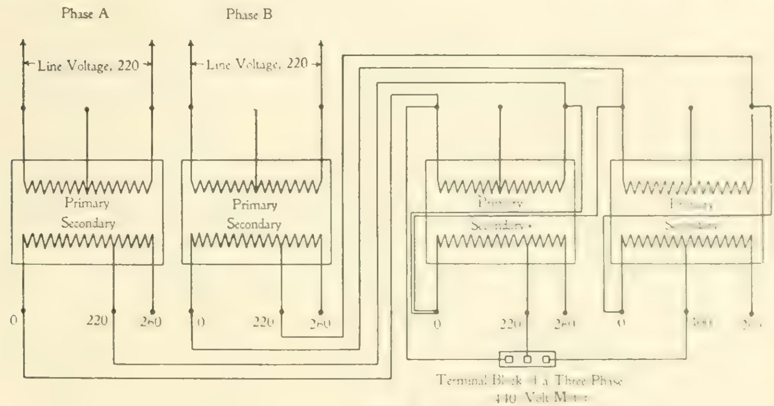


FIG. 81

The two phase-three phase transformation is therefore independent of the voltage impressed on these transformers.

EDITORIAL COMMENT

Imagination in Engineering

It is one thing to solve a problem which is definitely stated; it is quite another matter to formulate the problem from a lot of promiscuous data. It is one thing to design and assemble apparatus to meet specific requirements; it is quite another to decide what are the actual requirements to be met, or what will be the demands, when new methods produce new conditions.

The larger engineering problems involve indefinite data, and greater ability is required in their formulation than in their solution; they project into the future and must anticipate conditions for which there is no precedent.

For many years the increase in Bell telephone subscribers was about 10 per cent. per annum. For the past five years it has averaged 29 per cent. The number of subscribers' stations added last year was greater than the total number in 1897, after 21 years of growth. Should the engineer in laying out conduits and pole lines and switchboards provide for a continual doubling of subscribers every three years?

The street railway facilities in our large cities present a record which would be ludicrous were it not so serious. The horse-cars gave place to electric systems of large and rapid cars, but the crowding becomes denser. In Boston a subway was accepted as the solution, but passengers came faster than facilities; an elevated road was added and the subway was reconstructed to admit the larger cars; the facilities were still insufficient and the platforms were reconstructed for longer trains. In New York with its extended surface system, its elevated roads and new subway, it may be questioned whether the probability of getting a seat was not better in horse-car days than it is at present.

Telephony and traction are not simple self-contained problems; they react on social and business life. People form new habits. The more they talk and travel, the more they need to talk and travel. The telephone—the high-speed tool of the business world—intensifies activity and requires more telephones. Facilities for travel induce more travel. The telephone and the electric car are not passive elements in modern progress—they are active accelerating forces which increase its rate.

What is true in larger things prevails in smaller ones as well. Some time ago a motor was to be placed in a sawmill. Measurements indicated a trifle over 20 hp was being used. A 30 hp motor was installed. A year later the investigation of a complaint showed an actual output of nearly 40 hp and the motor was replaced by another of 50 hp. When there was a reliable motor behind the saw it was discovered that an increased rate of feed was possible and the output of mill and of motor were far more than anticipated.

Many electric plants—central station, railway, transmission, industrial—have required not merely increase, but reconstruction and change of system or method because the original provision for development was entirely inadequate as the future had not been correctly gauged.

Imagination is essential to the engineer—a constructive, creative imagination, tempered by experience and level-headed judgment, which can anticipate conditions not known to experience and foresee the means of meeting them. The engineer who cannot see beyond the present is not a safe guide.

CHAS. F. SCOTT.

Automatic Synchronizing

"Why has this not been done before?" is the first question that naturally arises on reading the description of an automatic synchronizer set forth on another page of this issue. As we see it, the answer to this question lies in the hesitation on the part of most central station engineers to trust the operation of synchronizing to any mechanical device. The argument is about as follows: Synchronizing is a very delicate operation and one that requires the most skill of any which the operator is called upon to perform. It is an operation which requires intelligence and a mistake or misjudgment is apt to be followed by serious results. As long as we have human intelligence, we do not care to entrust this task to a machine.

But this argument was ever futile in hindering the use of helpful invention.

It must be granted that the operation of synchronizing is one that requires skill and judgment. But the skill and judgment used are in proportion to the salary of the operator. The salary of such positions is not and naturally cannot be sufficient to employ the highest attainable skill. On the other hand, the machine for accomplishing this same duty is designed by men who to the highest

degree are expert in their "fact" knowledge of synchronizing. These men have studied every phase of the problem and have put brains into the apparatus they design. Those who use the automatic device for synchronizing are therefore using not the intelligence of the ordinary operator but the high grade intelligence of the expert who has made special study of the problem.

Automatic synchronizing effects its end without the limitations imposed by erring judgment or uncertain nerves. One or more chances to throw the switch always pass the operator before he gets his bearings. But the machine selects the very first opportunity to synchronize.

P. M. LINCOLN.

The Manhattan Generator

Personal anecdotes of great men are the most interesting parts of their biographies. Likewise the best stories of a great machine may be told by the men by whom it was designed and tested and operated. And so the contributions of Mr. Lamme and Mr. Gaillard and Mr. Stott are welcome variations from the ordinary accounts of machines and of power houses.

The Manhattan machines are notable for several reasons. They are the largest dynamos ever built. A new type of mechanical construction was employed. New machine shop methods were devised—notably the use of the transit for laying off the castings for machining. The generators were constructed in place in the power house—it was not feasible to ship in one piece a machine which was load for a dozen freight cars—and yet the design, manufacture, erection and operation of these machines followed one another smoothly and without serious mishap until eight of them in the 74th Street or Manhattan power house and nine of them in the 59th Street or Subway power house were operating together. They now supply to the elevated and subway divisions of the Interborough Rapid Transit Company a greater amount of power than is found in any other system. And they do it so well that only a few per cent. of the delays to traffic are chargeable to failure of motive power.

But progress is so rapid that these stations with machines which are nearly perfect of their kind are scarcely completed before a new type appears. Both stations already have steam turbines. It is not unlikely that in size these generators may continue for many years to come to be the largest ever built.

FORMULAE FOR THE WIRE TABLE

By HAROLD PENDER

In reading the article in the April number of THE ELECTRIC CLUB JOURNAL on "How to Remember the Wire Table," it occurred to me that the following formulæ might prove of interest to JOURNAL readers.

Let n = number of wire B. & S. gauge.
Then for copper wire at O° C.:

Resistance: $R = .1 \times 2^{\frac{n}{3}}$ ohms.

Weight:

$W = \frac{320}{2^{\frac{n}{3}}}$ lbs. per 1,000 feet.

$W' = \frac{1686}{2^{\frac{n}{3}}}$ lbs. per mile.

Area: $CM = \frac{106000}{2^{\frac{n}{3}}}$ circular mils.

Diameter: $D = \sqrt{CM} = \sqrt{\frac{106000}{2^{\frac{n}{3}}}}$ mils.

For sizes expressed as so many ciphers, take n negative and equal to the number of ciphers less one. For example, for No. 0000, n = -- 3.

The value of 2 with any index is readily found by expressing $\frac{n}{3}$ as a mixed number and operating with the whole number and the fraction separately. For example, for n = 16,

$$2^{16/3} = 2^{5\,1/3} = 2^5 \times 2^{1/3} = 32 \times 1.26 = 40.32.$$

The following values are easily remembered:

$$2^{1/3} = 1.26$$

$$2^{2/3} = 1.59$$

[The formulæ given by Mr. Pender express in a different form the rules laid down by Mr. Scott in the last issue of the JOURNAL. Many will doubtless find the rules more easily remembered and applied than the formulæ. The values 1.26 and 1.59 which are given above, will be recognized as approximately equal to the 1.25 and 1.60 employed in the former article.]

THE GROWTH OF ELECTRICAL INVESTMENTS

The application of electricity to the needs of public service corporations has, in but little over a single decade, resulted in the investment in the United States alone of nearly three billions of dollars through approximately 5,000 companies, having a present gross annual income estimated at four millions of dollars. During these ten years the United States has reversed its position in the financial world from that of a debtor to that of a creditor nation. During this period, investment in lighting and power installations has increased 300 per cent, and in electric railways, 500 per cent.

THE ENGINEERING APPRENTICES' CLUB HOUSE

THE ENGINEERING APPRENTICES' CLUB

By a Member

The apprentices of the British Westinghouse Electric and Manufacturing Company, Limited, feeling the need of both a social and an engineering fraternity, have organized a club at Trafford Park, near the works.

The idea was originated in the early months of 1903, at which time, however, the number of apprentices was not large enough to perfect an organization. Later, as the number of apprentices increased, a public meeting was called and the club in its present condition was established with about fifty charter members and a rapidly growing roll.

The movement has thoroughly met the approval of the men of the company. W. C. Mitchell, superintendent of works, was elected president, and several of the vice presidents' chairs were filled by other members of the work's staff.

The objects of the club are (1) to promote sociability among the apprentices, (2) to further the one common interest of all, namely, the engineering interest, by the presentation of papers upon engineering subjects and by the establishing of debating classes, (3) to provide wholesome recreation in which all members of the club could unite.

The original and ultimate aims of the Apprentice Club have been along the same lines as those of The Electric Club at Pittsburg—to create good fellowship and distribute engineering knowledge.

The club building is very appropriate for the present requirements. It is located near the works and near the rooms of the majority of the apprentices. The lecture room is, of course, the principal feature of the building, but a library, reading room and game rooms are also provided, so that the atmosphere is truly one of club life.

The sports are divided among

committees as motoring, football, cricket, swimming, tennis, etc.

The majority of the apprentices are students of the Institution of Electrical Engineers, of which there is a student section in Manchester. Apprentices are admitted to the regular meetings of the Institution held in Manchester. The various technical colleges in the vicinity also afford excellent advantages for educational purposes.

PERSONAL MENTION

Fred C. Farquharson has completed his apprenticeship course and accepted a position with the Allis-Chalmers Company.

Mr. A. S. Hatch, formerly of the Public Lighting Commission of the city of Detroit, Mich., is now engaged in consulting and contracting work in the same city.

Mr. Chas. Buttonfield, of the detail supply correspondence department of the Electric Company, has accepted a position with the Allis-Chalmers Company, with headquarters at Atlanta, Ga.

Mr. P. N. Nunn, chief engineer of the Ontario Power Company, lectured before The Electric Club Wednesday evening, April 26, on "Some Experiences with Electric Plants in the Rocky Mountains."

Mr. Raymond Dill, of the A. C. correspondence department of the Electric Company, has accepted a position with the Allis-Chalmers Company.

Mr. J. F. Vaughn, of Stone and Webster, consulting engineers, lectured before The Electric Club Thursday evening, April 27, on "The Puyallup Water Power Development and High Tension Transmission to Seattle and Tacoma, Wash.

Mr. P. H. Thomas, chief electrician of the Cooper Hewitt Electric Company lectured before The Electric Club Friday evening, April 28, on "The Cooper Hewitt vapor converter."

Mr. L. L. Gaillard, until recently electrical superintendent with the Interborough Rapid Transit Company of New York, has become associated in an engineering capacity with the Consolidated Railway Company at New Haven.

Mr. L. B. Breed, foreman of the dynamo testing department, has been transferred to the D. C. correspondance department as department engineer.

Mr. J. C. Foster, assistant foreman of the dynamo testing department, has been made foreman, with Mr. H. C. Specht assistant foreman.

Mr. Charles R. Underhill, recently chief electrical engineer of the Varley Duplex Magnet Company, has opened an office at 55 Liberty street for practice as a consulting electrical engineer. One of his specialties will be the design of power electromagnets. Mr. Underhill is the author of a book entitled "The Electromagnet," which treats the subject from the standpoint of design.

WITH THE PUBLISHERS

Mr. Chas. L. Clarke, chairman of the Editing Committee of the American Institute of Electrical Engineers, writes as follows:

THE ELECTRIC CLUB JOURNAL:

"Mr. Wardlaw's paper on 'Engineering Shorthand' is timely and right to the point.

"The fundamental reasons for the unwarranted liberties taken with the English language, the bad grammar and the worse syntax, so common in technical writings, are due to the fact that as young men, engineers are too much taken up with their technical work to think of studying grammar and composition; and to the more important fact that technical institutions of learning utterly neglect to teach these branches, or even try to impress upon the student the importance of being able to write correct, plain English."

Very truly yours,
Chas. L. Clarke.

In 1900 there appeared the first edition of a work on polyphase apparatus which has since come to be widely read. Although a volume of 250 odd pages, it devoted just twenty lines to synchronizing devices. The first five of these advert to the lamp method, the next eight to an acoustic synchronizer that never got beyond the laboratory door, and the last seven to a low frequency synchroscope just developed by the Westinghouse company.

Since the publication of this book most of the large power plants in America have been built, and the problem of paralleling their generator units has assumed foremost importance. It has been successfully solved. Of the many devices proposed a number of commercial instruments have been built. But all devices heretofore employed have required the throwing of the generator switch by hand. Elsewhere in this issue of the JOURNAL will be found an account of an instrument which does away with even this and makes the act of synchronizing completely automatic. All of which shows us the rapid progress of useful invention in the electrical arts and emphasizes the need of keeping abreast of it.

Michael Faraday, who was perhaps the greatest physicist that ever lived, was not a man whose knowledge of mathematics extended beyond trigonometry. Yet he was able to lay hold of difficult physical problems, to solve them and to expound their theory without the aid of mathematics. By experimental methods he developed and formulated that beautiful theory of electricity which later found expression in Maxwell's classical work. He was the first man in England to popularize science.

No more admirable purpose could guide an electrical magazine in its effort to instruct readers, and it is the intention of the JOURNAL to keep as far as possible away from mathematical exposition and to confine itself to the setting forth of engineering practice, methods, and apparatus in as clear and concise expression as possible. Vain speculation, mathematical dreaming and obscure ideas of irresponsible writers will find no room. We shall deal with engineering realities, the things tried and proven and actual achievements in the electrical field. Through it all we shall endeavor to weave the binding threads of sound sober theory.

A DIFFICULT PIECE OF CONSTRUCTION WORK

This photograph shows the installation of a 400-kw generator at the Basin Mills Station of the Orono Pulp and Paper Company, Stillwater, Me. The revolving field being lowered, weighs about five tons. The power house was constructed after the generators were installed.

THE

ELECTRIC JOURNAL

VOL. II JUNE, 1905 No. 6

TRANSFORMER INSULATION

RELATION OF OHMIC RESISTANCE AND DIELECTRIC STRENGTH

By O. B. MOORE

WHILE the subject of insulation is a very broad one, more or less essential to all branches of electrical construction, I shall deal only with its particular application to transformers. The principal characteristics of insulation for transformers, however, apply in a large measure to almost all electrical apparatus, the difference being more in degree and application rather than in principle.

The electrical characteristics of a transformer are mostly dependent upon the quality, arrangement and proportion of the iron and copper that enter into its construction; that is to say, they are practically independent of the insulation. This statement may seem absurd on the face of it, since a transformer will not operate without insulation in its make-up, but the fact remains that the less space occupied by the insulation, the more efficient the transformer will be with a given amount of iron and copper. Insulation, however, of necessity performs a very important function; for in a transformer the conductors are usually in the form of wire, wound into one or more coils, each comprising several layers of one or more turns per layer. In operation, each turn, layer and coil is at a potential different from its adjacent turn, layer or coil, and the whole operates at some potential different from that of the earth. The separate parts of course must be insulated one from the other and the whole from the earth. These points are among the first the student of electricity learns.

The primary function of insulation, then, is to insulate; to enable an electrical conductor to carry a current at some definite potential. The structure of the transformer and the conditions under

which it usually operates are such that its insulation is subject to various forces, electrical, mechanical and chemical. The life of a transformer, then, depends upon the fitness of the insulation put into it to survive the various conditions under which it is forced to operate.

In the study of this subject one is naturally led to ask, Why does a thing insulate? R. A. Fessenden has well expressed it by saying: "A thing insulates because it is possessed of two distinct properties; first, the ability to stand the mechanical and electrical stresses (and I wish to add another—chemical) due to the voltage used; and second, a conductivity such that but a negligibly small current can flow through it and leak away. In other words, it will neither allow the current to break through it nor to steal through it. The first property is called by Maxwell the dielectric strength of the insulator. The other property is called the ohmic resistance. The two together form its insulating power."

Another property should be considered, which in high tension work has come to play a very important part, namely, the specific inductive capacity.*

Electrical work is divided into two branches wherein the requirements for insulation are widely different. In apparatus used for the transmission of intelligence (telephony and telegraphy) the voltages are low, so the dielectric strength is of relatively small importance; but the currents used are small, the circuits long, and an insulating material of high ohmic resistance is needed. On the other hand in apparatus designed for the generation and transmission of electrical energy, where the currents are large and where the voltages are high, dielectric strength is the property mainly desired, as the leakage of a small amount of current is not objectionable. This difference of requirement for an insulator in the two branches of electrical work naturally gives to the general term "insulation" a double significance—to one branch meaning something having high ohmic resistance, and to the other meaning something which has dielectric strength. This double meaning has often lead to confusion, for their meaning is quite different, since an insulator may have a high ohmic resistance and at the same time not resist high voltage to breakdown.

In the insulation of electrical apparatus used for the generation

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*See "Insulating Materials in High-Tension Cables," by E. Jona, delegate of Assozion Electrotecnic Italiana, presented at the International Electrical Congress, St. Louis, 1904.

and transmission of power, the dielectric strength is of the greater importance, the electrical resistance having relatively little value. Steinmetz has remarked—I do not recall the exact wording—it is a very nice thing indeed—on paper—to read that the insulation resistance of a transformer, for instance, is 25 or 30 megohms, or even higher; but when the insulation resistance has been determined in the usual way, as shown in Fig. 1, by the application of 500 volts direct current through a voltmeter and suitable resistance in series with the insulation to be measured; it is not so nice in switching in your transformer upon the line for the first time to have an inductive or static charge break through 25 or more megohms, reducing the insulation resistance to practically nothing and burning out the transformer.

But on the other hand, the insulation resistance of a transformer may be suspiciously low—only a few hundred thousand

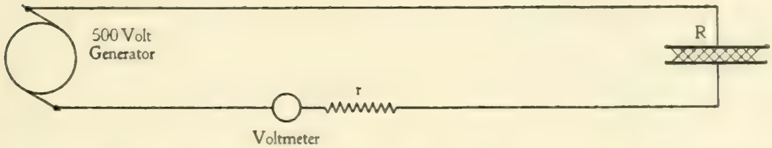


FIG. 1—CONNECTIONS FOR DETERMINING THE OHMIC RESISTANCE OF INSULATION

$$R = r\left(\frac{v}{v_1} - 1\right)$$

where r = internal resistance of the voltmeter, plus the series resistance.
v = potential of the circuit, usually 500 volts.
v_1 = reading on voltmeter.
R = required resistance of the insulation.

ohms—and still it may run continuously for years under average conditions of load without breaking down, even getting better as the insulating material dries out by the heat developed in it when running.

What is needed then, is to insulate the electrical circuits of the transformer so that it will operate without breaking down under all reasonable conditions of service. The insulation resistance gives no definite information as to the reliability of the insulation in a transformer. Air, which is about the poorest insulator in disruptive strength, has a very high ohmic resistance, while on the other hand, the insulating materials having the best disruptive strength such as mica, have a comparatively low ohmic resistance.

To see this more plainly, let us examine the behavior of different insulating materials.

Take for instance two metallic plates and separate them by an air gap of say .004 inch. Now, measure the insulation resistance

of the air at 100 volts difference of potential between the plates. It is higher than can be measured by means of the best instruments. Now raise the potential difference between the plates to 500 volts. A spark will pass across the gap and the insulation resistance which a moment before was infinite is now reduced to practically zero; it is broken down. Now insert in the air gap a piece of solid, dry insulating material, such as a piece of paper of the same thickness, and the insulation resistance will be measurable and very much smaller than the resistance of the air gap. Again, raise the potential to 500 or 1 000 volts and the piece of paper will withstand the pressure. If the paper is replaced by a sheet of mica of the same thickness its insulation resistance will be much smaller than that of the paper, to say nothing of the air. But the difference of potential at the terminals may now be raised to 10 000 volts or more and the mica sheet will not break down. "The electricity will rush out from the terminal plates upon the mica sheet in long, glowing streamers, beating against the mica with a hissing noise and forming a broad electrostatic aurora of violet light, and still the mica will not break down." This is the property desired. If this disruptive strength has anything in common with insulation resistance, its relation is not known. On the contrary, it seems that those insulating materials which have the highest resistance, like air, just happen to have the lowest disruptive strength, while those materials like mica which are relatively inferior in ohmic resistance, stand the electrical stress the best. Consequently, the measured ohmic resistance of a transformer or other apparatus will not indicate its disruptive strength. As can readily be seen there may be two bare wires almost touching each other, but with a thin film of air between, giving a very high ohmic resistance which, upon applying normal voltage to the apparatus, will most likely break down instantly. On the other hand, the wires in a transformer may be insulated with material such as fibre or mica and if the insulation be a little damp—measuring perhaps only a few hundred thousand ohms resistance—and the transformer be put into service, its ohmic resistance will increase, likewise its dielectric strength will improve and the transformer will not break down.

A very high ohmic resistance is, therefore, not a measure of the reliability of the transformer against breakdowns.

The above considerations, then, in a measure indicate the proper method of determining the fitness of insulation to withstand the conditions under which it is forced to operate; that is, in testing

samples we should actually subject them to an electrostatic stress until they break down and judge their quality by their dielectric strength, and not by their specific ohmic resistance. If the ohmic resistance is very low—comparatively speaking—the current which leaks through the insulation may be too small to do any harm. Ohmic resistance tests on transformers are of relative value only in so far as they give a clue as to whether there is somewhere a weak spot due to dirt and moisture, but this is not necessarily so.

They will not show how reliable it is. But if we apply a potential between the various parts of the circuit several times greater than that at which it normally operates without breaking it down, we have some assurance, then, other things being equal, that it will operate safely.

The following curves are from actual tests made upon certain

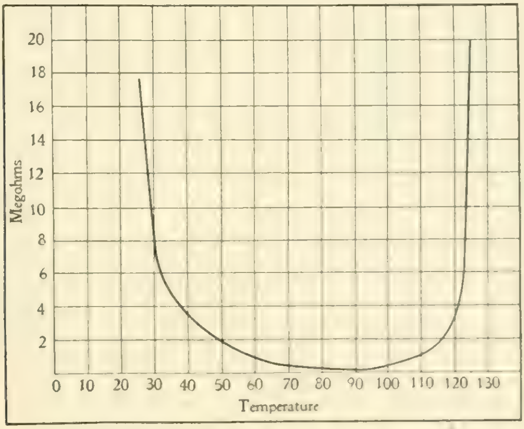


FIG. 2—A CHARACTERISTIC CURVE OF THE OHMIC RESISTANCE OF A THIN SHEET OF UNTREATED FIBROUS INSULATING MATERIAL

untreated insulating materials and transformers which were exposed to excessive moisture for the purpose of determining the best treatment to prevent the absorption of moisture and consequent low ohmic resistance and dielectric strength. These curves therefore may be taken as characteristic of the behavior of moist insulation when being dried by the heat developed in the windings under load. The measurements were made with commercial instruments. The sensibility of the voltmeter used was $5 \times 10^{[illegible]}$ amperes per scale division.

On account of this marked variation of the ohmic resistance

and dielectric strength due to the absorption of moisture, it is the present practice to treat all insulating materials and windings with moisture repellants in order to prevent the comparatively low resistance and dielectric strength shown in the curves.

Fig. 2 is a characteristic curve of the ohmic resistance of a thin sheet of untreated fibrous insulating material taken from stock and subjected to a drying process.

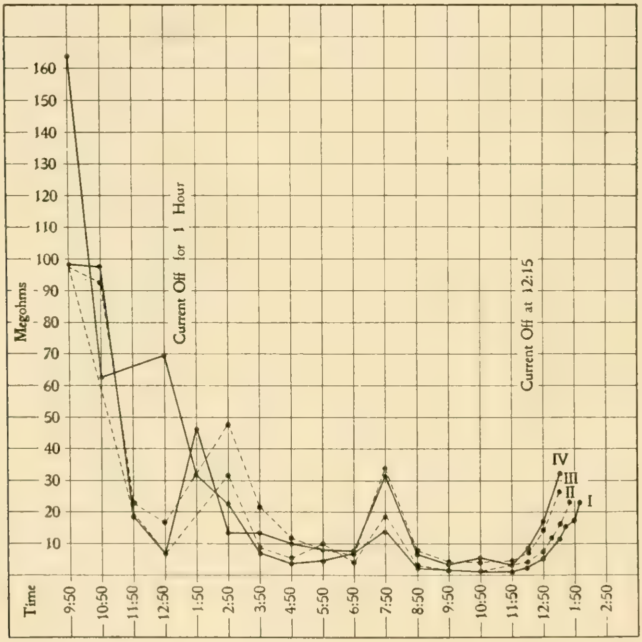


FIG. 3—OHMIC RESISTANCE OF THE INSULATION OF FOUR SIMILAR SMALL LIGHTING TRANSFORMERS DURING THE DRYING-OUT PROCESS

Fig. 3 shows curves of the ohmic resistance of the insulation during the drying-out process of four similar small lighting transformers whose insulation as a whole was not very impervious to moisture. After drying, however, the transformers were subjected to severe insulation tests without breaking down.

Fig. 4 shows single ohmic resistance measurements on each of a number of similar small transformers of various sizes. The ohmic resistances were measured after normal temperature runs and then the transformers were subjected to severe disruptive tests.

The transformers marked ⊙ broke down. It is evident that if these transformers had been thoroughly dried out none would have broken down, and results similar to Fig. 3 would have been obtained.

In the above curves the following general points may be noted:

(1) The ohmic resistance and dielectric strength of moist insulation are higher when cold than when hot.

(2) In expelling the moisture from a transformer it is bound to accumulate more or less in certain parts owing to the complex structure of the transformer, thereby causing the ohmic resistance to vary considerably until such an amount is expelled that the

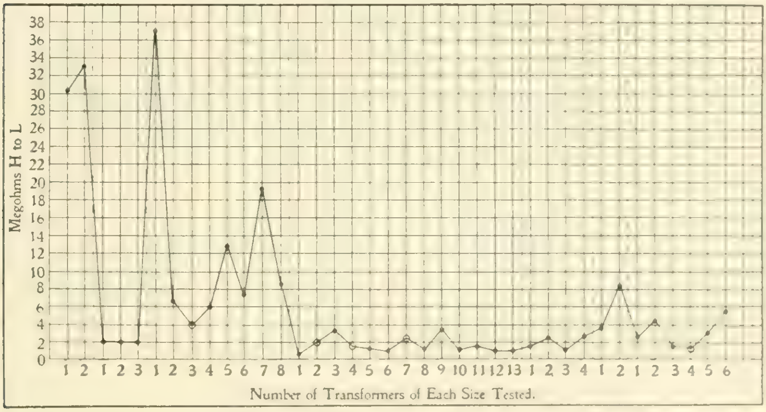


FIG. 4—SINGLE INSULATION RESISTANCE MEASUREMENTS ON A NUMBER OF SIMILAR TRANSFORMERS OF VARIOUS SIZES

remaining moisture passes out at a diminishing rate, when the ohmic resistance will begin to rise as shown in Fig. 3.

(3) In the case of a thin sheet of insulating material, where the moisture is free to get out at all points without accumulating perceptibly at any one place, the ohmic resistance will gradually decrease to a minimum and then increase gradually, forming practically a smooth curve as indicated in Fig. 2.

(4) The decrease in ohmic resistance with the rise of temperature is evidently due to the presence of moisture (provided no chemical changes take place), for after the moisture is expelled the resistance increases with increased temperature, within certain limits.

(5) Low ohmic resistance is not necessarily an indication of poor insulation, but probably an indication of the condition of the apparatus in regard to moisture.

(6) A high e. m. f. should not be applied to apparatus when the ohmic resistance of the insulation is low.

(7) Material which is badly deteriorated mechanically by heat may still have a high ohmic resistance but very poor insulating qualities.

In conclusion, then—as stated before—the ohmic resistance tests of insulation is of relative value only. The same readings may be obtained twice from the same apparatus under entirely different conditions of real dielectric or volt resisting value. There is no direct relation between the breaking down e. m. f. and the ohmic resistance. However, a low ohmic resistance usually means a low breakdown test, but a low breakdown test does not necessarily mean a low ohmic resistance. These two tests have been aptly compared to the chemical analysis and the tensile strength of iron. A poor chemical analysis means poor physical qualities, but a good chemical analysis does not indicate whether or not there are flaws in the metal.

The principle use, then, of ohmic resistance measurements of insulation lies in the comparison they afford of the damp-proof qualities of various dielectrics and in the measure of the degree of dryness attained in drying out a piece of electrical apparatus.

If a transformer or other similar apparatus is suspected of containing moisture especially when wound for very high voltages, a drying-out process should be applied immediately before placing the apparatus in service or where it will not be unduly exposed to moisture.*

The presence of moisture in connection with most all forms of insulation is the principal source of trouble, being especially true in such insulating liquids as transformer oils.†

*See "Methods of Drying Out High Tension Transformers," by J. S. Peck—*The Electric Club Journal*, Vol. I. p. 61.

†See "Transformer Oil," by C. E. Skinner—*The Electric Club Journal*, Vol. I, p. 227.

ARMATURE WINDINGS OF ALTERNATORS

PART I—OPEN-TYPE WINDINGS

By F. D. NEWBURY

ANY armature winding may be considered as made up of a number of similar parts or units, this unit being a single conductor. The action of the winding in the generation of electromotive force depends primarily on the action of these single conductors. The electromotive force generated by the complete winding is determined, in the first place, by the electromotive force generated in a single wire and, in the second place, by the way in which these unit electromotive forces add and subtract when the single conductors are connected together. It is from this point of view that the following description of armature windings has been written, explaining the characteristics of the unit electromotive forces and, after this, explaining how the single wires are connected to-

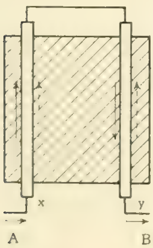


FIG. 1

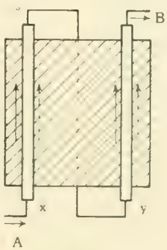


FIG. 2

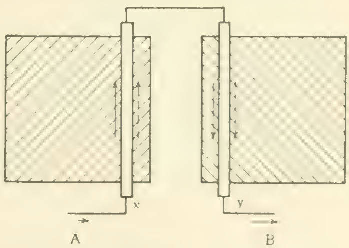


FIG. 3

gether to form the various types of practical windings and the characteristics of the electromotive forces that result from these various connections.

Any wire moving across a magnetic field will have an e. m. f. generated between its ends that will be proportional to the strength and distribution of the magnetic field and to the rate of motion of the wire. This e. m. f. varies in value as the wire passes different points on the field pole, and alternates from positive to negative as the wire passes from one pole to the next. Each wire on the armature has such an e. m. f. generated in it, varying in the same way and alternating in the same way. These single wires form the units of the armature winding and the similar e. m. f.'s in them form the units of the armature voltage.

But while these unit e. m. f.'s are identical in form and value

they differ in one very important respect—a difference which makes polyphase currents possible. Because different wires have different positions on the armature the e. m. f.'s in them do not have the same value at the same time. The e. m. f. in any one wire will reach its maximum as that wire enters the strongest field, and as different wires, due to their location in different armature slots, enter the strongest field one after another, so the maximum values of the e. m. f.'s in different wires will occur one after another. With armature slots regularly spaced the maximum values of the e. m. f.'s in the wires in the different slots will occur at regular intervals. This means that there is a difference in phase between the e. m. f.'s in the wires in the different slots, and this difference in phase is due entirely to the difference in location.

It amounts to the same thing to say that the phase of the e. m. f. generated in a wire on the armature is continually changing as the armature turns, i. e., as the wire occupies different positions. As the wire moves from the center of one pole to the center of the next pole of the same polarity the phase of the e. m. f. changes through a complete cycle, or, two wires a distance apart on the armature corresponding to two poles will have e. m. f.'s in them differing in phase by 360 degrees or one complete cycle. For this reason the space on the armature circumference equivalent to two poles is said to equal 360 electrical degrees, and any part of this space equals a proportionate part of 360 degrees.

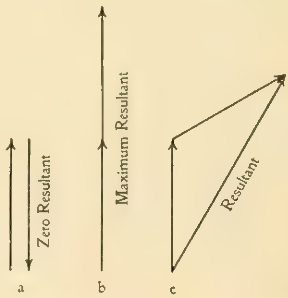


FIG. 4

A single wire may be a complete armature winding in itself but it would not be a very useful winding. For most practical purposes greater e. m. f.'s are needed than can be generated in a single wire. It is necessary to connect a number of wires together to produce a greater e. m. f. It is therefore necessary to know how to connect these wires together so that they will produce a greater e. m. f. The e. m. f.'s in two wires will add together when the directions of the two e. m. f.'s are the same with respect to the common circuit of which the two wires form a part. In Fig. 1 starting from the terminal *A* the direction of the common circuit is up in the wire *x* and down in the wire *y* as shown by the full-line arrows. As-

sume the two wires to be under the same pole; the e. m. f.'s in them will be in the same direction at the same time—that is, they will both be positive or will both be negative. This direction of the e. m. f.'s is shown by the dotted line arrows. Under these conditions the two e. m. f.'s are in opposite directions with respect to the common circuit and in consequence they will subtract. Suppose the end connections between the same two wires be changed to those shown in Fig. 2. Then the two e. m. f.'s will be in the same direction with respect to the common circuit and they will add; the e. m. f. across the terminals *AB* will be the sum of the two individual e. m. f.'s. Suppose that the two wires are connected together as in Fig. 1, but that they are under poles of opposite polarity as in Fig. 3. Then with the direction of the common circuit in the two wires as shown and with the two e. m. f.'s in the two wires in opposite directions the two e. m. f.'s will add just as in the second example. With the conditions of Fig. 1 but with the two wires located one over the other the e. m. f. across the terminals *AB* will be continuously zero. With the conditions of Fig. 3 (it should be noted that the connections here are the same as in Fig. 1) and with the two wires separated on the armature by a distance equal to the pitch of the poles, the e. m. f. across the terminals will be a maximum. With the same connections but with the conductors spaced between these two limiting positions the resulting e. m. f. will be between the corresponding zero and maximum values. These three conditions are shown vectorially in Fig. 4, in which the individual voltages are represented by lines of equal length but in different phase positions.

With the armature in the position in which the maximum e. m. f. is generated the separate wires should be marked with arrows in one or another direction representing the positive or negative e. m. f.'s generated in them in that position of the armature. The different wires should then be connected together so that all these arrows are in the same direction with respect to the common circuit; or, in other words, the wires should be so connected together that in tracing the circuit from one terminal to the other all of the e. m. f. arrows are in the same relative direction as that in which the circuit is traced. When this condition is fulfilled the separate e. m. f.'s will add together, giving the maximum possible total e. m. f.

The various types of alternating-current armature windings may be conveniently divided into two classes: Open-type windings,

which include windings which do not in themselves form a closed circuit, and closed-type or re-entrant windings, which include windings which do form one or more locally closed circuits. Both of these classes of windings are sub-divided into single-phase, two-phase and three-phase windings.

SINGLE-PHASE OPEN-TYPE WINDINGS

Single-phase open-type windings are the simplest forms of winding. The active wires composing the winding are connected together in one circuit and the two ends of the open circuit thus formed are the two terminals of the winding. Fig. 5 is a winding of this type, having one slot per pole. The single wires of this

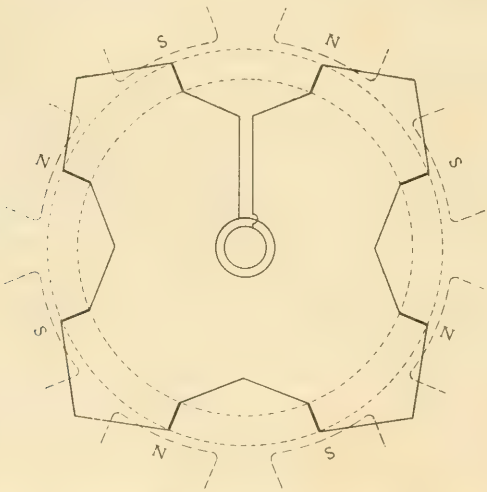


FIG. 5—SINGLE-PHASE WINDING—ONE SLOT PER POLE

winding are connected together as in the elementary diagram Fig. 3, and the wires so connected being a distance apart corresponding to the pitch of the poles. The unit e. m. f.'s are all in phase and will add together as shown in Fig. 4b. With more than one slot per pole the proper connection of the different wires requires the application of no new principle; the different wires may be connected together in any convenient order, provided that when the armature is in the position in which the maximum e. m. f. is generated all of the individual e. m. f.'s are in the same direction with respect to the common armature circuit.

The generation of e. m. f. by the winding is a simple matter of addition of the e. m. f.'s in the single wires and it makes no differ-

ence so far as the resulting e. m. f. is concerned in what order the e. m. f.'s are added. Mechanical considerations, however, limit the ways in which the wires can be connected together. Of the possible methods of connection one is preeminently the best under all conditions met with in single-phase open windings and is the method

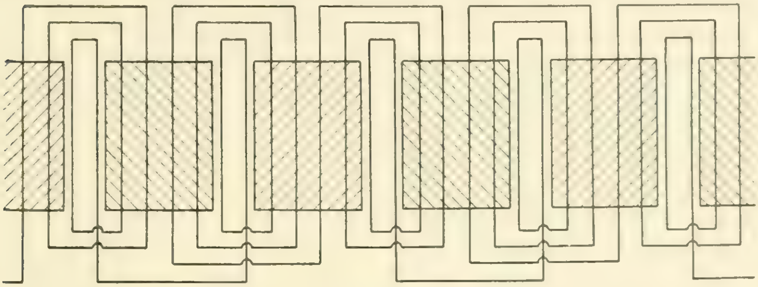


FIG. 6—SINGLE-PHASE WINDING — UNIFORMLY SPACED SLOTS

invariably used. This is shown diagrammatically in Fig. 6. The distinctive features are the use of a very simple form of coil and the division of the coils of one pole into two groups. If these coils were arranged in one group the winding would require double the number of different sized coils and double the space for the end connections. While these windings are sometimes made with equally spaced slots, as shown in Fig. 6, they are more frequently made with the slots concentrated in groups, as shown in Fig. 7. The reason for this arrangement of slots is the higher e. m f. obtained

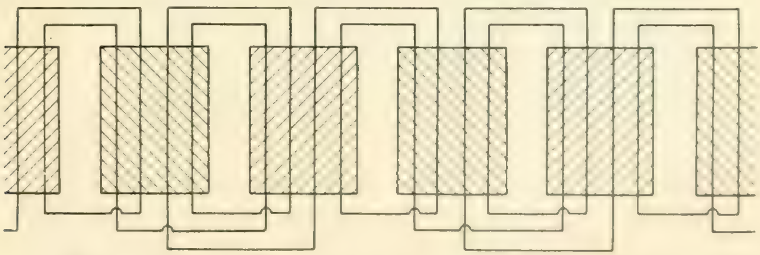


FIG. 7—SINGLE-PHASE WINDING — UNEQUALLY SPACED SLOTS

from a given number of conductors, other things being equal. When the slots are brought closer together the separate e. m. f.'s are brought nearer in phase, which results in a greater total e. m. f. when they are added together. The impossibility of taking advantage of this arrangement in single-phase windings without leaving a part of the armature core unoccupied is an indirect rea-

son for the low kilowatt rating obtainable from single-phase generators in comparison with polyphase generators of the same dimensions.

It has been pointed out that there is a certain flexibility in the connections of single-phase windings. This is true of all open alternating-current windings, single-phase or polyphase. In closed windings for either direct current or alternating current, with a given type of winding and with a given number of field poles only one arrangement of parallel circuits is possible. With alternating-current open-type windings, on the contrary, the same winding may be connected in a number of different combinations of parallel circuits, thereby obtaining various voltages from the same armature. In the single-phase winding, shown in Fig. 6, there may be as many different arrangements of connections as there are multiples of the groups of coils or, what is the same thing, multiples of the number of field poles. For example, with six poles the six groups may be connected in series, three groups may be connected in series and two such circuits connected in parallel, two groups may be connected in series and three such circuits connected in parallel, or, finally, the six groups may be connected in parallel. In general, any group of conductors in the winding may be connected in parallel with another group, provided the two e. m. f.'s generated in the two groups are the same in wave form, magnitude and phase relation. It amounts to the same thing to say that two groups of conductors may be connected in parallel when they contain equal numbers of conductors and occupy identical positions with respect to different field poles of the same polarity.

EXPERIENCES ON THE ROAD

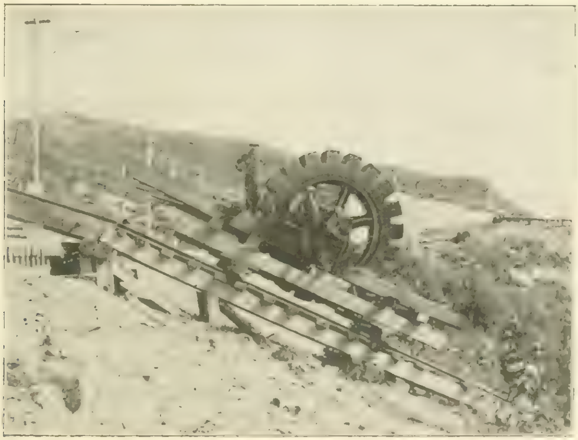
By B. C. SHIPMAN

In writing an article of this kind, of necessity one deals with his own experiences, and he must be forgiven if he make a liberal use of the first personal pronoun.

Beginning with small things, I will relate a curious phenomenon which presented some features rather startling to me, who firmly believed all self-respecting generators obeyed some laws as stringent as those of the Medes and Persians.

A GENERATOR WITH BACK LEAD

This particular generator was a 1.5 kw of a prehistoric period, but for all that, doing yeoman service in an antiquated plant, which



SKIDDING A LARGE ROTATING FIELD DOWN THE HILLSIDE—SHAWINIGIN WATER POWER COMPANY, QUEBEC, CAN.

at one time had produced all the carborundum made, and which, I believe, had the honor of producing the first sample made under the direction of Mr. Acheson. It was used as an exciter to an alternator and had never given any trouble until a short time before when it burnt out and was rewound at our factory. After its rewinding it was impossible to hold up the voltage on the alternator, no voltmeter or other instrument being in the circuit of the exciter. A thorough examination of the exciter and its circuit failed to reveal any cause for its not delivering proper voltage to the alternator,

except perhaps that it sparked slightly. In endeavoring to remove the sparking, a really surprising result was discovered. Rocking the brushes backward raised the voltage and took the spark away.

Of course the natural conclusion was that the throw of leads had been made wrong in the rewinding, but on cutting off the canvas head such was not found to be the case at all. The leads were absolutely correct, and as they were before rewinding. Repeated trials showed conclusively that the brushes should be set back far beyond their proper position, which was fixed to a certain extent by the design of the machine, and it was impossible to get the brushes back as far as they should go. As the machine had to be in operation that night, and as I did not particularly like that part of the country as a residence for a longer period than absolutely necessary, it was a "rush" job of disconnecting all the leads of the commutator to see if any coils were wrongly connected. When the last lead came from its commutator bar, the cause of the trouble was disclosed. The commutator was loose on the shaft, being of a type held in place by a cup setscrew and no key; and the drag of the brushes was sufficient to rotate it around the shaft through quite an arc, although when the machine was standing still the spring of the leads would pull it back into place. The last lead was soldered back just in time to catch the seven o'clock train for town.

BRUSH TROUBLE

An equally simple thing, but which was threatening much more serious consequences, was the case of an 800 kw, 550-volt, direct-current, engine-type railway generator. This machine had been installed for a couple of years, and had been very unsatisfactory, indisputably so, since its commutator had to be turned very regularly once a month during that time. Nothing seemed to do it any good, except turning, and even that was only a palliative. Considerable time and effort had been spent in redesigning it, so to speak, that is, putting extra balancing rings on the back of the armature, and chipping the pole faces. As far as saving the commutator went, the power-house records showed that these efforts went for naught. The symptoms in the case were as follows: After turning, the generator would start off beautifully, takings all kinds of load from 25 to 175 per cent., without showing a sign of it; pretty good proof that it was electrically all right. After a few days of this angelic operation a small spark would begin under the brushes and day after day would get worse until at the end of

three weeks or a month, if allowed to continue so long, the fire thrown from under each brush would be four or five inches long in times of heavy load, sometimes flashing the machine. The first view I had of the machine in its quiescent state. It had just been turned the day before. The power-house attendants assured me that every attention was given the machine, every kind of commutator lubricant and all ranges of brush tension had been tried, with absolutely no appreciable improvement in its operation. This, by the way, illustrates the fallibility of human testimony.

The brushes were found to have a tension of about nine to eleven pounds each. The only remedy applied was the reduction of this tension to two or two and a half pounds. The machine has never since given trouble.

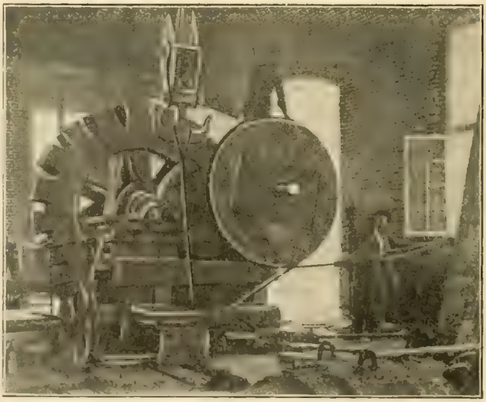
An amusing incident happened in connection with the investigation of this machine which has also a moral. As soon as the generator was shut down after my arrival, an engineer of the engineering department and myself started from opposite sides of the generator up over the brush holders examining various details as we climbed. We noticed a broad smile pass around among the power-house operators, and on pressing for an explanation, we were told that the last one of our men to investigate this machine had told them "that was probably the only trouble; if they would keep off the brush holders it would be all right." All of which illustrates pretty well that a roadman should never lay the blame of the trouble in a machine to the operators, unless he has positive proof; something more than his inability to find any other explanation. It creates an antagonistic spirit at once and as a result one finds himself hampered and inconvenienced in many ways. Furthermore, experience proves that electrical machinery is so thoroughly automatic that it will stand almost any amount of carelessness and abuse without developing troubles, and it is safe to say in case of trouble, that in nine cases out of ten, the cause had best be sought in the machine itself or its operating conditions, rather than in the inattention or abuse it has received from the operator. I have without a single exception found operators extremely desirous of keeping their equipment in good shape, and have known them to nurse a troublesome machine even more than their job called for.

REPAIRING FIELD COILS

To show what can be done to prevent shutdowns, and also to illustrate the hardiness of electrical apparatus, I may cite the

case of a 5-hp, 500-volt, type M motor which was a very important part of an equipment in which it drove a set of reversible clutches, a water pump, an air pump and lowering and raising mechanism. This complete apparatus worked twenty-two hours out of the twenty-four, and a shutdown of the motor put a 30 000 dollar plant out of business with a loss of income of 264 dollars a day. It was of course very poor policy not to have extra parts or even a whole motor on hand, but such was the case. Duplicate parts were ordered soon thereafter. Owing to the clutches sometimes sticking, the motor would flash and the arc flare up against the field coils. A very few of these arcs would burn through the taping of the field coils into the winding, and thus cause an open field. We repaired this motor several times, and the repair did not take more than three minutes by the clock, as it consisted only in bunching all the ends of the wires of the field winding we could see, and twisting them together to complete the field circuit. The amount of field winding gradually cut out of circuit by repeated repairs of this nature, did not

MANIPULATION OF THE GRACEFUL WRENCHES



THE WAY THE SPIDERS WERE FINALLY PRESSED ON THEIR SHAFTS

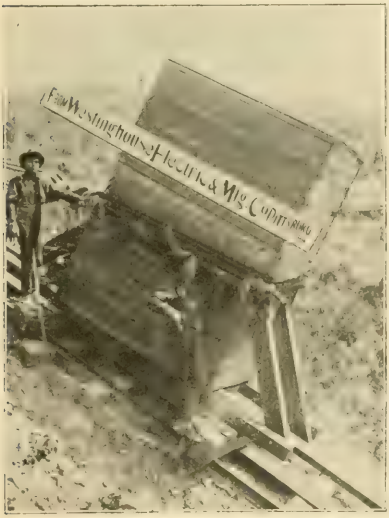
seem to affect the operation of the motor in the slightest degree, and no ill effects could be observed.

PRESSING TWO SPIDERS ON THEIR SHAFTS

A little more difficult job later presented itself when a couple of twenty-three inch shafts were to be pressed into their spiders. The only consoling fact about the case was that they fitted; they had already been pressed in at the shop and removed again for shipment. The further pleasant information was given that it took three hundred tons for the job. To produce three hundred tons pressure the shop had carefully and thoughtfully provided two five-ton yokes, two bolts fourteen feet long by six inches in diameter, threaded with V threads instead of square, two hexagon nuts for said bolts measuring about nine inches between faces, and a couple of light and graceful wrenches seven feet long weighing just about eight hundred pounds apiece. Many times I sat down on and pondered over those wrenches. As the shop had so nonchalantly furnished them, it seemed to be up to me to use them. The location of this plant I might state here is about eighty miles from anywhere, and I doubt if an hydraulic press of such a size was known in that country. When the rig was finally set up, four men were required to put the wrench on the nut, so a block and fall was rigged to carry the wrench. The next point was to turn it. All the men that could hang on the end of it could not budge it, so a double block and fall was rigged to the end of the wrench, and six lusty dagoes manned the luff end of it. As only a sixth of a turn could be gotten from one direction of pull, a series of blocks and tackle had to be rigged up tangent to the arc of revolution of the wrench at various points. This served to turn first one wrench and then the other, but at the rate of progress being made, working night and day with relays of men, it appeared after careful figuring that it would take twenty-eight days to put one spider on. Then the skin on the dagoes' hands turned out to be softer than the rope, so that a winch was substituted and the dagoes put on that. To add to the wretchedness of the situation, the V threads would burr from the yoke, as it was impossible with the constant pulling first in one direction and then in another, to keep the yoke from rubbing against them.

Two days and two nights of this convinced us of the futility of further work along this line. There was no hope of an hydraulic press, so we made a wooden wheel six feet in diameter of three-inch

plank, two layers transversely to each other, and in the center bolted two one-half inch pieces of boiler plate on each side of the wheel, in which we cut a hexagon opening to fit the nine-inch nuts. Around the outside of the wheel a one-inch narrow plank lagging was nailed parallel to the axis, so as to provide a good surface for the rope. Three turns of two-inch rope were made around the outside of the wheel when placed on the nut and the rope led down through a snatch block in the floor and up to the crane hook. One man on the free end of the rope was easily able to hold it so that it would bind tightly on the wheel and the crane did the work of pressing in the shaft with neatness and dispatch. It took eight hours to finish the job.



SKIDDING A LARGE TRANSFORMER

Luck plays a large part in all construction work as in other work, but it is just as well not to count on it. It is sometimes bad instead of good. An instance of the latter kind, however, did befall me, which it may be instructive to relate. It points out very forcibly some of the fundamental principles of rigging (if I may be permitted the expression) and while perhaps well known to all construction men who "have been there," it may still be of use to those just trying their wings.

There were several large 2 200 kw transformers, weighing each about 50 000 lbs., to take down a very steep hill, and the only place to unload them was on the hillside where the railroad passed on a steep grade. The roadbed had been made by simply terracing the hillside, so that on one side of the railroad was a bank and on the other the slope over which the transformers were to slide. A skidway had been built down this slope into the transformer house, the last hundred feet or so being on trestle work over some large penstocks. The skidway consisted of ordinary railroad ties, on which were laid old rails, so that it was practically an inclined railroad. Three snubbing posts had been set at the railroad grade, two on the hill side of the track and one on the slope side. We unloaded the

transformer and got it two-thirds of the way down the hill without any trouble when darkness overtook us. In doing this we used the approved method of snubbing, where the luff end of the rope was taken two or three times around the first post and then two or three times around the second post, with a man to feed the rope at each post. The safety of this lies in the fact that although the second post normally performs no service whatever, yet in case the man at the first post should allow the rope to get away from him, it will be brought up very suddenly by binding on the second post. It is impossible to make a rope run when taken around two posts in series, without positive feeding.

When darkness interrupted the work we were informed that the railway track would have to be clear the first thing in the morning as some freight had to be taken over the line. Our ropes lay right over the track to the first snubbing post. Against my better judgment we decided to throw off the ropes from the two posts back of the track and move up to the one on the near side, even though there was no second post for safety. Blocking the transformer on the hillside, we did so, and awaited until the next morning to continue down the hill.

The next morning the transformer skid had to be started with a jack as it had stuck to the rails in standing all night, and the sudden start, with rope reeved five times through the blocks and somewhat slackened, made the luff end spin quite rapidly around the snubbing post. The "experienced" rigger we had hired especially for this job, got rattled and jumped away from the post, for fear of being caught in the whirling rope. The transformer cleared the two hundred feet into the transformer house in record time and landed as right as if it had been set down there by a crane. Why it did not jump the track on the trestles and drop on to the penstocks, I do not know. I was quite satisfied to think that it did not. I might here remark that this was an especially dangerous hill, and the transformer was not the only thing that ever got away on it. I once saw a load of penstock plates go down.

BLACKENING OF A COMMUTATOR

Another curious phenomenon which I have incidentally ran across in several cases is the peculiar blackening of commutators. The only machines in which I have observed it have been four-pole with wave-wound armatures, though I believe it is quite as

characteristic of any number of poles. In four-pole machines, blackening develops first at points diametrically opposite on the commutator and gradually spreads in one direction—against the direction of rotation—until the curious spectacle is shown of one quarter of the commutator black, the next quarter bright and perfect, the next quarter black and the fourth like the second. The starting line of the blackening is very sharply defined, the latter end not so much so, and if the action is allowed to continue the whole commutator will eventually get black. With a six-pole machine three equidistant points on the commutator show up, and in any case the number of points is equal to the number of pairs of poles. The cause of the trouble is in unequal spacing of the pole pieces, and the remedy lies in chipping them until the pole faces and pole spacing are equal.

PUMPING OF TWO DIRECT-CURRENT GENERATORS

A very curious spectacle and one not very soothing to a nervous temperament was presented in an installation I lately completed. We are all familiar with pumping or hunting of alternators and synchronous motors, but this experience of pumping between direct-current shunt generators has certainly been unique with me. The equipment consisted of four 1 250-hp, 300-volt, shunt generators, direct connected to water wheels. There were two generators to a wheel—one on either end. The plant was started under short notice and the brushes of the swivel type, were not ground in; consequently they sparked more or less, so that the exact neutral point was difficult if not impossible to get, for there was no cutting off the load to determine it.

Late one night a small "Canuck" appeared at my house as I was preparing for bed excitedly repeating, "O M'sieur, M'sieur! Dey want you at de 'batisse' quick, quick, quick!" The inhabitants always refer to a power house as "batisse electrique," and usually drop the "electrique." When finally I summoned enough French and English combined to inquire what the matter was, he almost shouted "De big w'eel's all fire, fire, fire!" Another idiosyncrasy of the inhabitant is to express the superlative degree by a triple repetition. A lantern and a pair of rubber boots were quickly obtained for the mile long muddy walk, but when I arrived at the power house all the machines were shut down, and the operating force in a flurry. The only description I could get of the trouble was that the ma-

chines for no apparent reason suddenly began to throw fire, first one and then another alternately, and the operator said he thought the two machines on one wheel were behaving this way. I ought to explain here that as this plant runs on practically a steady load night and day, no governors were installed, hand regulation only being used. Also because no speed indicators were installed it seemed possible that, owing to widely different speeds on the units, and hence different field excitations, a slight change of load might have upset an unstable condition of multiple operation, but in this event the trouble would have to appear between machines of different water wheels and not between those on the same wheel. We immediately started the plant again to verify this point. It went off very well, no trouble being experienced in putting the machines in multiple. I had about come to the conclusion that the operator must have had a "pipe dream," when suddenly one machine groaned, gave a slight spit, and then another machine groaned a little louder; and the noise passed back again to the first, the fire under the brushes getting a little more vicious at each instant. For a few moments it was impossible to discover which machines were showing the trouble, as all the ammeters were disturbed, and before we could definitely decide No. 2 unit had been cut free from the 'busses and the cylinder gate throttled. By this time it was evident where the trouble was. No. 1 unit was in full exhibition.

A generator would groan and throw a sheet of fire from under its brushes while *B* would be quiet. This condition would last for about two seconds, then the machines would exchange conditions. With each swing the ammeters would reverse. There was no question about it, first one machine would be a generator and the other a motor, and then vice versa; both of them on the same shaft.

The cause of the trouble, which fortunately was very quickly found, arose from the fact that the brushes were not placed in similar commutative positions on the two machines. Whatever the position of the brushes, it did not make any difference so long as the load remained steady, as perfect adjustment could be had by the field rheostat, but any considerable change of output upset the condition of equality of potential difference between the machines, and so the one delivering the lowest voltage would become a motor while the other would remain a generator. But this action itself would immediately cause a readjustment of voltages, the generator dropping below the motor, and of course the action would immedi-

ately reverse, ad infinitum and cumulatively. The cause once known, the remedy was easily applied, and the machines were back in service within a few hours.

A TRANSFORMER KINK

An incident which did not fall directly under my observation, but which I can nevertheless describe, may be interesting. This was a case where some transformers had been installed and were so satisfactory that the order was repeated. Between orders, however, the manufacturing company had improved its designs apparently. The new transformers arrived and were put into service, running in multiple with the old ones, on both high and low tension. No ammeters were in the circuits of the individual transformers. In about five hours the whole lot of new transformers went up in smoke. Investigation showed that their regulation was much superior to the old ones, and when they were supposed to be running on about full-load, they were really carrying not only their own full-load, but also that of the old ones too.

DRYING OUT TRANSFORMERS

A point which I do not think the average engineer appreciates is the length of time it takes to dry out transformers under certain conditions. Of course the ideal way is to heat the transformer in a vacuum, finally admitting the oil before destroying the vacuum. This is also the quickest way, but it is seldom that any facilities are found so that advantage can be taken of this method.* Then recourse must be had to heating either by currrent in the coils of the transformer itself, or by heat generated externally. The former is the only one of the two worth considering if one has a choice. The usual assumption that a few days of drying at a temperature of about 90°C. fits a transformer for use, while applicable perhaps to the majority of cases, is not reliable in the case of high voltage transformers. I had one high voltage transformer that had to be kept at the above temperature for two months and a half before being thoroughly dry, and out of fourteen others that had not been as carefully protected as they might have been before erection, five of them went over two months before the insulation resistance was high enough to be considered satisfactory. The method of testing

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*See Methods of Drying Out Transformers, *The Electric Club Journal,* Vol. I., p. 61.

the insulation resistance, with a high resistance voltmeter using as high a voltage as possible, has with me always given unfailing indications of the condition of the transformer.

A REMARKABLE CASE OF RESUSCITATION

As a last but not least experience of interest and use to roadmen, I will mention a remarkable case of resuscitation accomplished on a man who received about 12 000 volts. We were running a load test on the transformers of this plant, and the bare high tension wires were led directly from the transformers out of the windows and to plates dipping in the river. The voltage was 25 000 and the arrangement two-phase, all four plates being in the river at the same time. In corroborating the fact that the man received 12 000 volts, experiment developed that practically the whole resistance of this natural water rheostat lay in the contact resistance between the plate and the water, and not in the distance of the path between the plates. A distance of forty feet between plates produced no measurably different load than a distance of twenty feet, with equal amounts of submersion. Hence the whole body of water and earth adjacent was practically at a midway potential between the two wires. The workman, in direct violation of orders, stepped upon a brick and concrete platform immediately over the water where the plates were hung and his head came in contact with one of the wires. In falling he broke from the top of his head an arc about eighteen inches long. His head was burned completely to the bone, as were also his feet, though slightly. By vigorous working he was brought around in three-quarters of an hour, and after dressing went fishing the next day. Without doubt he must have had a cast iron constitution, but it shows what is possible in case of electric shock.

In the running of this test a great number of dead fish floated up to the surface from between the rheostat plates, and the peculiar fact was noted that many of them were distorted, being bent somewhat at right angles in the middle of the body. An explanation of this condition of the fish was sought by the operators, who gathered them in, from the assembled electrical sharps. All passed it up until our erstwhile chief of the transformer division opined that it gave a beautiful illustration of the quarter phase current, as the fish were killed in a two-phase rheostat.

135-TON SINGLE-PHASE LOCOMOTIVE HAULING A TRAIN OF 50 GONDOLA STEEL CARS

This locomotive has developed a draw-bar pull as high as 65 000 lbs. The locomotive is made in two parts each fitted with six drivers and three 225 hp motors. The trolley voltage is 6 600.

A 135-TON SINGLE-PHASE LOCOMOTIVE

BY N. W. STORER

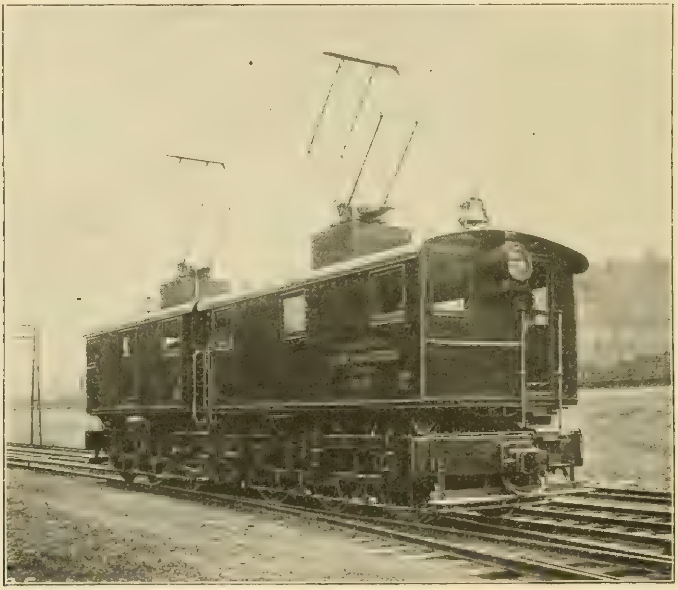
Ever since the advent of the successful single-phase railway motor was announced by Mr. B. G. Lamme in September of 1902, the world has been expectantly awaiting the application of this type of motor to the heavy railway work, for which it is eminently fitted.

While a number of roads have been for some time in successful operation with single cars with two or four motor equipments, and some small locomotives have been built, the great 135-ton locomotive which was exhibited by the Westinghouse Electric & Manufacturing Company to the delegates of the International Railway Congress on their visit to Pittsburg May 16th is the first single-phase locomotive yet built for heavy traction. While many doubts have been expressed by those who favor direct current as to the ability of single-phase motors to exert a heavy starting tractive effort the Westinghouse Company has stood steadfastly in favor of a single-phase system and in order to effectually demonstrate its practicability for heavy service has built this huge locomotive, believing that an actual demonstration even at great expense is the best answer to all arguments.

The tests on the locomotive were carried along in connection with tests on the friction draft gear, automatic air-hose couplings and improved air brake appliances which were made by the Westinghouse Air Brake Company. The train used in the tests consisted of fifty new steel cars weighing 45 000 pounds each or approximately 1 125 tons total and having a total length of 2 200 feet. This weight, however, does not give a true idea of the power exerted by the locomotive in accelerating and maintaining it at full speed as the cars were new and the bearings were stiff and the train was started on a sharp curve. The Air Brake Company had provided one of the largest steam locomotives built by the Pennsylvania Railroad Company for making their tests and it was plain from its labored exhaust that the train was a heavy load for it. The contrast between the electric and steam locomotives was never more apparent than when the electric locomotive picked up the train without the slightest apparent effort and accelerated it rapidly to full speed. On this occasion the time was so limited that it was impossible to make extensive tests for the benefit of the delegates

but sufficient was shown to them to prove that the single-phase locomotive is a factor to be reckoned with in future railroading.

From tests which have since been made with a dynamometer car attached, a steady draw bar pull of as high as 65 000 pounds has been developed without the use of sand and with no perceptible slipping of the wheels. This 50-car train has in fact been handled successfully by one-half of the locomotive, on which occasion it developed a maximum draw bar pull of 49 000 pounds. In order



135-TON SINGLE-PHASE LOCOMOTIVE OPERATING ON A TROLLEY VOLTAGE OF 6 600. THE LOCOMOTIVE IS MADE IN TWO PARTS EACH CAPABLE OF OPERATING ALONE

to exert this draw bar pull, however, a liberal use of sand was necessary.

The complete locomotive was designed for freight service with a rating of 50 000 pounds draw bar pull at 10 miles per hour and a speed of 30 miles per hour at light load. These preliminary tests have fully met the expectations of the designers of the locomotive.

The locomotive is unique in many respects. It is operated with a line voltage of 6 600 volts. Current is taken from the overhead wire by a sliding shoe supported by a pantagraph trolley. Voltage control by means of induction regulators is used. There is a motor-driven blower in each cab which supplies air for the forced ventilation of transformers, regulators and motors.

The locomotive is built in two parts, the equipments of which are complete and duplicates. The mechanical parts were built by the Baldwin Locomotive Works and evidences of their careful design and workmanship are plainly seen in the massive frame as well as in the numerous details which are so necessary to a good locomotive.

Each half of the locomotive has three 8-inch axles with 60-inch wheels. Each axle has a 225-horse power single reduction motor geared to it with a gear ratio of 95:18. The motor has eight poles, each having its own magnetizing field coil. A neutralizing winding lies in slots in the faces of the poles. The field coils and neutralizing winding are connected in series with the armature at all times. The motor is wound for a normal voltage of 325 and operates at a speed of about 320 revolutions per minute at full load. The commutation is very satisfactory at all times. The efficiency and power factor are 86.6 and 86.5 per cent. at normal load and 86.5 and 95.5 respectively at half load. The motor is designed for a frequency of 25 cycles. The tests show conclusively that large motors are perfectly practicable even for very low speeds.

HOW TO CALCULATE REGULATION

SIMPLE METHODS OF CALCULATING THE REGULATION OF ALTERNATING CURRENT CIRCUITS

By J. S. PECK

ALMOST all engineering specialists have certain short cuts, by the use of which they are able to arrive at approximate results with a speed which to one unacquainted with their methods appears truly marvellous. In the April issue of the JOURNAL Mr. Scott tells "How to Remember the Wire Table," his method being to learn the rules governing the arrangement of the table, and to remember the diameter, weight and resistance of one size of wire. With this information it is possible to obtain approximately the characteristics of any size of wire, and to make rapid mental calculations.

The determination of the regulation (total drop) of a circuit containing ohmic resistance and self-induction with loads of different power-factors is at first sight a somewhat difficult problem, but by remembering a few simple rules it may be calculated mentally with a considerable degree of accuracy.

CASE I.

To determine the regulation of a circuit containing resistance and self-induction when supplying a non inductive load.

RULE

To the ohmic volts in per cent. add the square of the inductive volts, in per cent., divided by 200.

EXAMPLE

Ohmic volts$=10$ per cent.

Inductive volts$=14$ per cent.

Power-factor of load$=100$ per cent.; required the regulation.

Regulation$=10+\frac{14^2}{200}=11$ per cent.

The reason for this rule may be seen by referring to Fig. 1, from which it is evident that the regulation of the circuit is equal to the difference between line voltage and load voltage,

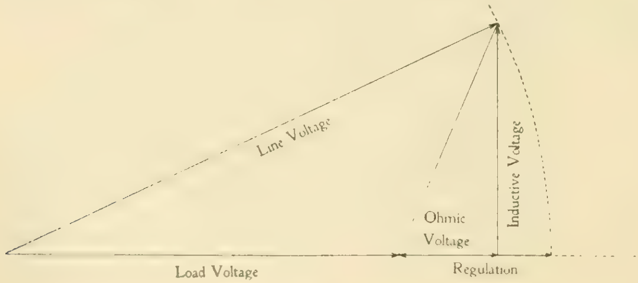


FIG. 1

or to the ohmic voltage plus the versine of the angle whose sine is equal to the inductive voltage.

It will be found from trigonometric tables that for small angles, the versine varies as the square of the sine, also that the versine of the angle whose sine is .14 is approximately $.01=1$ per cent., therefore for a sine of .1 the versine is $.01\times\frac{1^2}{14^2}=.005=.5$ per cent., and for a sine of .28 the versine is $.01\times\frac{28^2}{14^2}=.04=4$ per cent. Thus, if it is remembered that 1 per cent. is added to the ohmic voltage for an inductive voltage of 14 per cent., the value to be added for different inductive voltages may be calculated easily.

The same result is obtained by squaring the inductive voltage and dividing it by 200, as given in the formula above. The

formula is easily remembered, and enables the regulation of a circuit to be determined quickly and with considerable accuracy.

CASE II

To determine the total drop in a circuit containing resistance and self-induction when a load of less than 100 per cent. power-factor is supplied.

RULE

Multiply the ohmic voltage in per cent. by the power-factor of the load and the inductive voltage in per cent. by the reactive factor of the load. The sum of the products is the total drop.

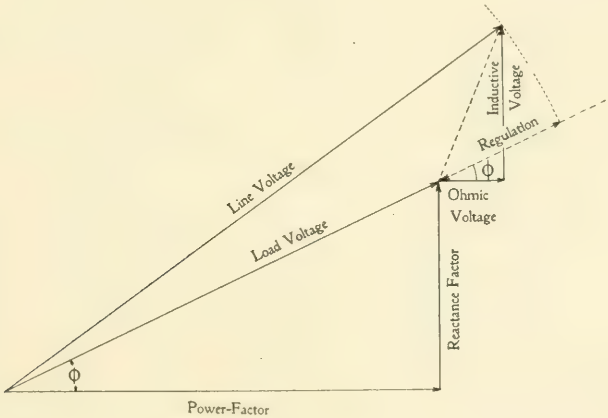


FIG. 2

The reactive factor is the wattless component of the load, and equals sine $\Phi = \sqrt{1 - P.\ F.^2}$. where sine Φ is the angle of lag.

EXAMPLE

Power-factor=80 per cent.=.8.

Ohmic voltage=10 per cent.

Reactive voltage=14 per cent.; required the regulation.

Reactive factor$=\sqrt{1-.8^2}=.6=60$ per cent.

Regulation$=(10 \times .80)+(14 \times .60)=16.4$ per cent.

The construction in Fig. 2 shows the manner in which the rule is deduced.

The regulation is equal to the difference between the line voltage and the load voltage, and it is desired to obtain a simple relation between this drop and the ohmic volts, inductive volts

and power-factor. For any but very high power-factors the total drop is equal to the sum of the projections of the ohmic voltage and the inductive voltage upon the load voltage.

The projection of the ohmic voltage on the load voltage=ohmic voltage x (cosine Φ=power-factor).

The projection of inductive voltage on load voltage=inductive voltage x [cosine (90°—Φ)=reactive factor]. Therefore the regulation=ohmic drop x power-factor+reactive drop x reactive factor.

By remembering the reactive factor for certain power-factors, the regulation of a circuit may be calculated mentally and without the use of charts or tables of any kind.

The reactive factors for a few of the most common power-factors are given in the table below:

Power-factors. cos Φ	Reactive factors. sin Φ
95 per cent.	31 per cent.
90 per cent.	43 per cent.
85 per cent.	53 per cent.
80 per cent.	60 per cent.
70 per cent.	70 per cent.
60 per cent.	80 per cent.

A consideration of these values in connection with Rule II indicates that for power-factors above 70 per cent., the ohmic voltage has relatively a greater effect upon the regulation than has the inductive voltage, while for 70 per cent. power-factor they have relatively equal effects, and for power-factors less than 70 per cent. the inductive voltage has relatively greater effect than the ohmic voltage upon the regulation. This last point brings out the fact that where the ohmic voltage is greater than the inductive, the regulation is better with a very low power-factor than with a high one.

STATIC DISTURBANCES IN TRANSFORMERS

By S. M. KINTNER

IT is a well known fact in the experience of operating engineers with transformers having a large ratio of transformation operating on high voltage lines, that there may occur momentarily, on the low tension side, voltages (to ground) greatly in excess of the normal potential. These momentary increases in the low tension voltages are commonly called "static disturbances" and in general, are the result of a change in the static balance of the high tension side and its connecting circuits. The following diagrams show the way in which static disturbances are induced.

In Fig. 1 the primary, secondary and iron are represented by *P, S* and *I* respectively. Between the primary and secondary, and between the secondary and iron, a number of small condensers are shown representing the capacity of these windings with respect to each other, and the capacity of the secondary (assumed in this case to be low tension) to ground.

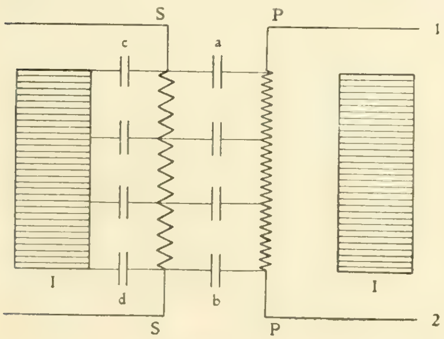


FIG. 1

The iron cores of most transformers are grounded, and if both lines connected to the high tension or primary side are equally well insulated, their difference above or below earth potential will always be equal in amount but of opposite polarity.

By following the diagram, Fig. 1 from line 1 through the small condenser *a* to the secondary, then from it back to line 2 at the opposite end of the primary through condenser *b*, it will be seen that the secondary has zero static induction from the primary. This is evident on the assumption of equal capacities in *a* and *b*, and the other small condensers (not lettered) between them, as the voltage between lines 1 and 2 will divide inversely as the capacities.

In Fig. 2 is shown a static diagram developed from Fig. 1 in which the small condensers are considered concentrated in two

The capacity to ground of the low tension winding is represented as concentrated in one, shown at *c-d*.

If one side of the high tension winding becomes grounded then the potential of its two sides lose its balance with reference to earth and an inspection of the diagram shows that the secondary winding has an induced charge from the primary which raises its potential abnormally above that of ground.

Reference to Fig. 2 shows that if line 2, for instance, is grounded then condensers *b* and *c-d* will be in multiple and these again in series with condenser *a*. Thus the high potential is distributed across that circuit inversely as the capacities, and on the assumption of all three being equal, the line connecting *b* and *c-d* to *a* (the secondary winding) will have one-third of the line potential of the high side above earth.

Variations in the capacity to ground of the low tension side and its connections thus determine the value of this abnormal voltage. In general, it can hardly be expected to exceed one-third of the line voltage on the high tension side. In a transformer with a high ratio of transformation these static disturbances on the low tension side may cause serious strains in its insulation unless certain precautions are taken to prevent it. It is more serious in high ratio transformers simply because its insulation is less able to withstand it, as the induced static voltage is independent of the ratio of tranformation.

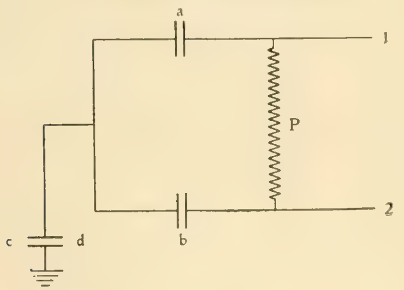


FIG. 2

One method used for relieving this disturbance is to connect a discharge spark gap between the middle point of the low tension side of the transformer to be protected and ground. The spark gap opening is such that any voltage, very much in excess of the maximum normal one, will cause it to discharge and thus the low tension side is practically tied to ground during such a disturbance, while at other times it is free. No difficulty is encountered so long as single transformers working alone are being used, but when single transformers are worked in groups for polyphase transformations, it is possible to get into trouble by improperly connecting these dischargers to the group.

Fig. 3 illustrates the groupings commonly employed and shows the spark gap connections. The low tension windings only are shown, as the connection of the high tension is in general immaterial. It will be noted that only one spark gap is used in all the groups save that of the two-phase independent

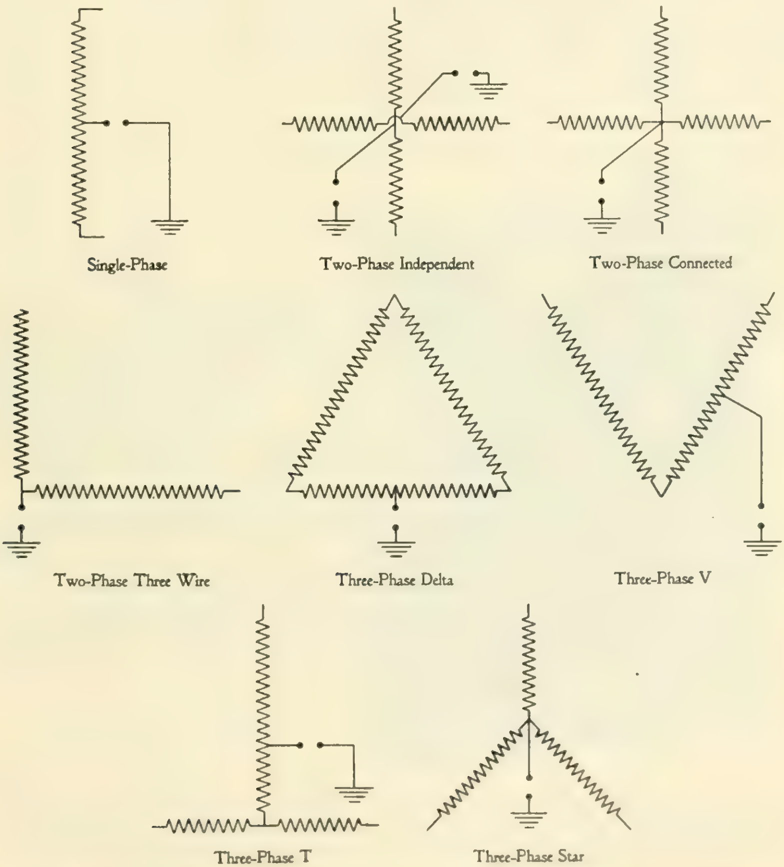


FIG. 3—LOCATION OF SPARK GAP DISCHARGERS FOR VARIOUS ARRANGEMENTS OF TRANSFORMERS

circuit, which is in reality two independent single-phase circuits.

The gap should be attached to the neutral point of the group when possible, and under all conditions it should be attached as near to that point as possible. In the diagrams it is connected to the neutral point in all the arrangements excepting in the two-

phase three-wire, the three-phase △ and three-phase V. In these three cases the preferable connection is shown, the exact neutral point not being here available.

Any one of the transformers can be selected for the gap connection in the V or △ arrangement, though care must be taken to see that the same symmetrical arrangement of connection is observed on each of several groups if they may possibly be connected in parallel. Failure to observe this last mentioned caution may result in having two points in different legs of the △ or V connected to ground through two gaps, and a short circuit on the part of the group. Fig. 4 shows the result of a severe arc that was caused by having a gap on one and a ground on the other of two legs of a delta connected group of large transformers.

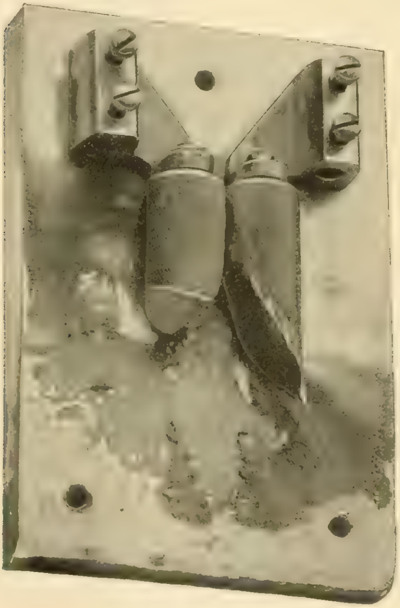


FIG. 4—THE REMAINS OF A SPARK GAP DISCHARGER OPERATING ON ONE LEG OF A DELTA WHEN A GROUND OCCURRED ON ANOTHER LEG

If the low tension side of a group of transformers is grounded either at the neutral or any other point, there is no need of any spark gaps as static dischargers, in fact they should never be used, as a short circuit will surely result when the gap discharges.

No spark gap dischargers should be used on transformers supplying a rotary converter that has one leg of its direct current circuit connected to ground for the same reason as above. Frequently the large amount of electrostatic capacity to ground of the circuits connected to the low tension side of high voltage transformers, particularly those having a great amount of underground cable, renders it unnecessary to provide any protection as the amount of static charge that reaches the low tension circuit is so slight in comparison to the large capacity that no serious voltages result from it.

DURABILITY OF STEAM TURBINE VANES

BY J. R. BIBBINS

Very recently a report* from German engineering circles relating to a life-test of a German-built Parsons turbine stated that after running 17 200 hours, practically day and night for two years, it was found that the vanes and all interior parts as well as the bearings showed not the slightest trace of wear.

A recent statement† by a British engineer who had been in charge of the same turbine station for eight years shows that during this period no wear was observed on the interior of the turbines. Two years later they were again opened up for his inspection, and on his

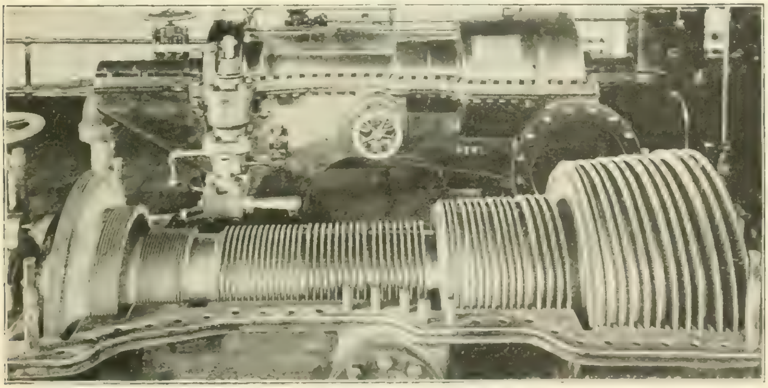


FIG. I—WESTINGHOUSE-PARSONS TURBINE NO. I, 400 KILOWATTS CAPACITY, WITH UPPER HALF OF STATOR REMOVED. IN CONTINUOUS SERVICE FOR NEARLY SIX YEARS

own statement "they were in as good a state as when they left the builders' works."

In American practice some excellent evidence has been found at the turbine plant of the Westinghouse Air Brake Company. The first machine of 400 kw was installed in August, 1899, and the plant has since been in continuous operation on the regular factory light and power load. This machine was opened in March of the present

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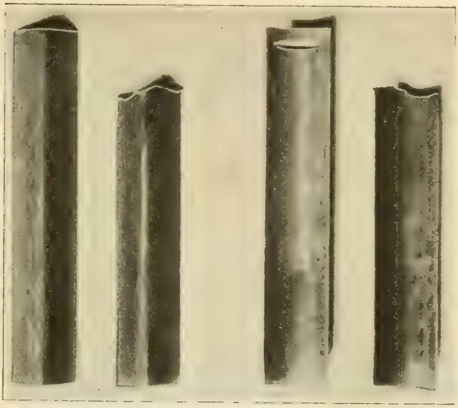
*Electrical Times, January 1905. The machine, a 600 hp Brown-Boveri-Parsons turbine, was installed at the Aschenborn pit in Silesia in 1902 and publicly sealed so that no adjustments or repairs were possible. A little over two years later these seals were broken in the presence of seventy engineers.

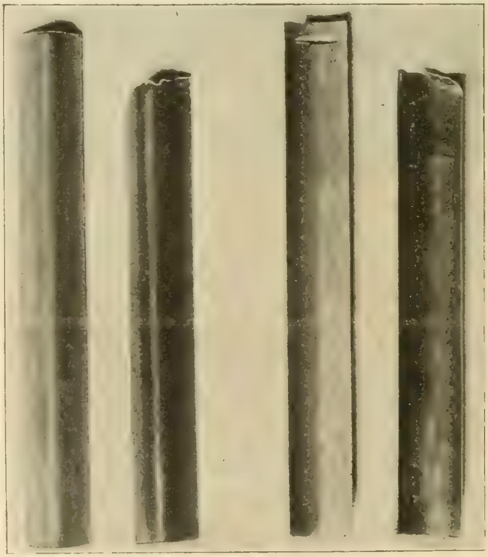
†J. H. Barker, Journal Institution of Electrical Engineers, May 12, 1904.

year, at which time the accompanying photographs were obtained. In order to show clearly the condition of the vanes, two sample blades were deliberately broken out of the eighth and twelfth rows respectively of the low pressure rotor barrel (shown at the right). Here the greatest quantity of moisture occurs in the expansion of steam, and here wear, from steam erosion would, if at all, be expected.



ABOUT ONE-HALF ACTUAL SIZE
FIG. 2—LOW PRESSURE VANE FROM TURBINE NO. I. EIGHTH ROW, LOW PRESSURE BARREL OF ROTOR. NEW VANE ALSO SHOWN FOR COMPARISON

Three facts are apparent from these exhibits: First, that the old vanes have retained their full cross section and consequently their full mechanical strength; second, the vane angles are unimpaired and hence their efficiency is permanent; third, the working steam surfaces have not lost their original smoothness.

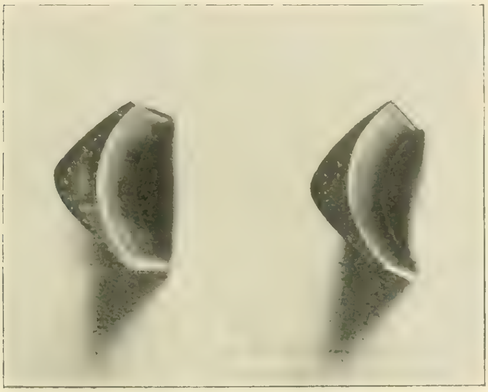


ABOUT ONE-HALF ACTUAL SIZE
FIG. 3—LOW PRESSURE VANE FROM TURBINE NO. I. TWELFTH ROW, LOW PRESSURE BARREL OF ROTOR. NEW VANE SHOWN FOR COMPARISON

The secret of the long life of vanes in the Parsons type of turbine lies in the low steam velocities employed. This desideratum is secured by utilizing the principle of compound-

ing. Instead of one expansion stage, there are fifty-eight in this size of turbine. In each the energy of velocity is abstracted by the moving vanes as fast as it is generated so that the steam velocities throughout the turbine range no higher than 150 to 600 feet per second, although the same result is accomplished as in the single stage turbine where a velocity of 4 000 feet per second may obtain.

Excellent results have certainly been secured from the turbine plant above mentioned, in view of the fact that the steam supply has been excessively wet, for water, even at comparatively low velocities, will in time abrade any material. On several occasions the turbines have been checked below their normal speed by slugs of water from the steam line. Frequently the city water supply fails and it becomes necessary to use creek water which is badly contaminated with sulphur and other impurities from the drainage of mines.



ONE AND ONE-THIRD ACTUAL SIZE

FIG. 4—SECTION OF NEW AND OF OLD LOW PRESSURE VANES AFTER NEARLY SIX YEARS OF SERVICE

The evidence here presented on the absence of vane wear is admittedly of a somewhat circumstantial character, and no tests have been made to determine directly the specific point of permanence of economy for long periods.* Yet turbo-mechanics prescribes definitely the laws and conditions of efficient working, and if we have succeeded in preventing a change of vane contour we have accomplished much. It should also be borne in mind that the turbine on exhibit represents the beginning of the American turbine industry, and with such results already attained it is reasonable to suppose that improved methods of manufacture and increased understanding of the turbine art have resulted in an improved machine.

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*Prof. Ewing, of Cambridge, tested, in 1902, a 500-kw Parsons turbine after one year's continuous service. The small increase in water rate—3 per cent.—observed was fully accounted for in the power required for driving condenser pumps, which, in the original tests, were driven independently of the turbine.

PROTECTIVE APPARATUS

PRESENT AMERICAN PRACTICE IN LIGHTNING ARRESTERS FOR LOW VOLTAGE TRANSMISSION CIRCUITS

By N. J. NEALL

THE design of lightning arresters began with the simple air gap for the passage of the static discharge from line to ground, but in order to suppress the short-circuit on the generator which almost always follows this discharge, nearly every known means for rupturing an arc has been suggested and patented. The combination of these two factors renders the problem of building successful arresters rather difficult and many methods have failed to come into practical use, chiefly on account of

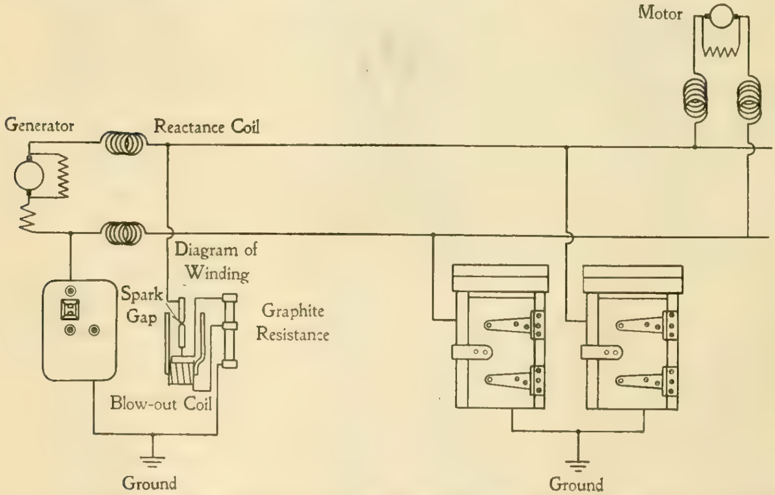


FIG. 1—CONNECTIONS FOR THE M D LIGHTNING ARRESTER FOR LIGHTING OR POWER CIRCUITS UP TO 850 VOLTS. METALLIC CIRCUITS ARE SHOWN HERE TO ILLUSTRATE THE PRINCIPLE OF THE MAGNETIC BLOW-OUT TYPE OF LIGHTNING ARRESTER.—GENERAL ELECTRIC COMPANY.

mechanical difficulties encountered in their working out. Simplicity of construction and operation is an essential.

In low voltage circuits the most important service is that required by railway circuits, lighting and power work up to 2,500 volts. It is imperative that the arresters be of low cost, offer protection at all times and have a long life. Their final breakdown must be positive and not endanger property by sustaining short-circuits.

For interurban railway and lighting service where the lines are exposed directly to storms, it is desirable to install arresters at such

frequent intervals that the line may be said fairly to bristle with discharge points. In cities railway lines are shielded by the surrounding houses in such a way that storms do not seriously affect them.

Arresters involve three main types of construction in their operation of suppressing the arc. (1) Magnetic blow-out, (2) non-arcing. (3) moving part.

Each type is suitable for use on either alternating-current or direct-current circuits within certain limitations. They may rather be classified according to the kind of service:

I. Direct Current.
1. Magnetic blow-out.
2. Moving part.
3. Non-arcing.
4. Coherer (an expression suggested by wireless telegraph practice).
   (a) loose.
   (b) fixed.

II. Alternating Current.
1. Moving part.
2. Non-arcing.
   (a) metal and multi-gap.
   (b) metal multi-gap, with resistance.
   (c) metal multi-gap, with diverging sides.
3. Coherer.
   (a) loose.
   (b) fixed.

I. Direct Current

Under their respective patents, several manufacturing companies are exploiting these types as follows:

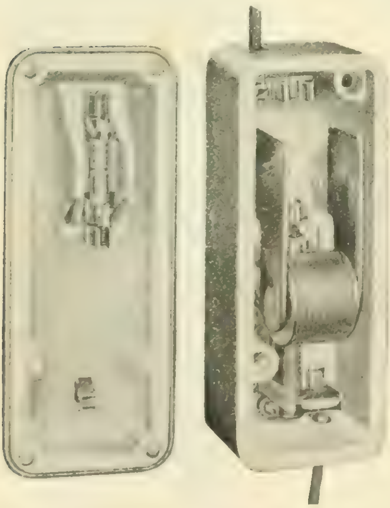


FIG. 2 MAGNETIC BLOW-OUT LIGHTNING ARRESTERS FOR DIRECT-CURRENT CIRCUITS, TYPE M D-2.—GENERAL ELECTRIC COMPANY

Figs. 1 and 2.

1. Magnetic blow-out. (General Electric Company.) One of the earliest forms of lighting arresters put into actual service was the magnetic blow-out type invented in 1884 by Prof. Elihu Thomson. The arrester has undergone very little change during the last fourteen years, excepting, of course, modifications in the arrangement of parts and in the method of blowing out the arc. The principle of its operation is shown in Fig. 1, where it is seen that if the static discharge in passing to ground is followed by line current it will pass through a coil shunted around a

part of the resistance pencil, thereby creating a magnetic field which is so placed as to blow out the arc formed by the short-circuit current flowing over the air gap. This principle of displacing the arc can be easily demonstrated by bringing a magnet near the arc of a lamp, and it will be seen that the arc is pushed away by the magnetic lines issuing from the pole of the magnet.

2. Moving part (Garton Daniels Company.)

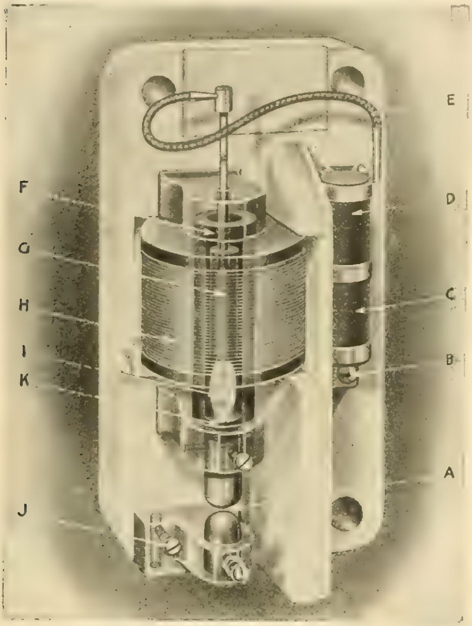


FIG. 3—MOVING PART LIGHTNING ARRESTER FOR DIRECT-CURRENT CIRCUITS SHOWING PRINCIPLE OF OPERATION.—GARTON DANIELS COMPANY

FIGS. 3 AND 4.

Only one arrester now in use bases its operation on the action of a moving part. Many other arresters have been tried on this basis, but the fact that they required a moving part usually operated against their permanence and prevented uniformly successful operation.

In the Garton arrester, Fig. 3, the short-circuit passing through a non-inductive resistance *C D* is partly shunted by a solenoid *H* operating a plunger *G* through which, by means of a flexible connection *E*, the remainder of the current is passing. With the energizing of the coil, the plunger is lifted violently,

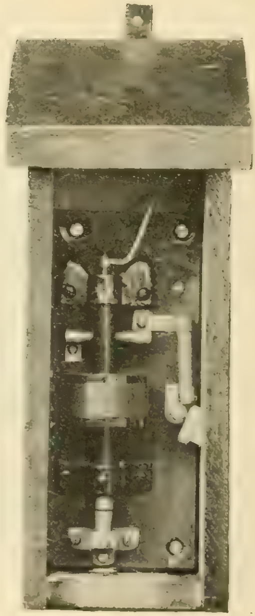


FIG. 4—MOVING PART LIGHTNING ARRESTER FOR RAILWAY SERVICE, 350 TO 750 VOLTS. — GARTON DANIELS COMPANY

thus drawing out an arc *I* in the insulated tube (the core of the solenoid). By reason of this attenuation in the confined space the arc is ruptured, after which the plunger drops to the normal position for another discharge.

3. Non-arcing. (Westinghouse Electric & Mfg. Company.) After many notable experiments in the development of lightning arresters, the form shown in Fig. 5 was brought out by Mr. A. J. Wurts.*

4. *a.* Coherer, loose. (Stanley Electric Company). See II. 3.

4. *b.* Coherer, fixed. (Westinghouse Electric & Mfg. Company.)

Although largely in use, the arrester shown in Fig. 5 has been lately superseded by the M. P. arrester, Fig. 6.†

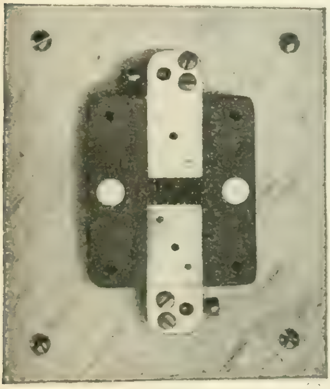


FIG. 5—SWITCHBOARD TYPE OF NON-ARCING LIGHTNING ARRESTER (COVER REMOVED) FOR DIRECT-CURRENT CIRCUITS.—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

From the description of the M. P. arrester already given, it is clear that it may be regarded as a fixed coherer. Its similarity both in construction and in operation with that of the coherer of wireless telegraphy is striking.

In the latter service a number of conducting particles are normally separated from one another so as to open-circuit a local battery system in which they are placed. With the arrival of the telegraphic waves the particles line up in such a way as to come in contact and close the local circuit, thereby transmitting a signal. After the cessation of the waves the particles resume their open position. The coherer must allow the waves to pass freely and not be affected by the local battery current, which is small. The M. P. lightning arrester on the contrary must respond equally as free to static waves, but it must also handle relatively high voltages. This condition does not require the contact of the particles because a certain very small gap is quite as good. This circumstance wonderfully simplifies the prob-

*See *The Electric Club Journal,* Vol. I., p. 36.
†See *The Electric Club Journal,* Vol. II., p. 229.

lem. The particles must then be so placed to pass the discharge freely but not allow short-circuit currents to follow.

II. Alternating Current

1. Moving part. (Garton Daniels Company.)

Same type for alternating current as for direct-current circuits, except the addition of air gaps (copper).

2. *(a)* Non-arcing metal and multi-gap. (Westinghouse Electric & Mfg. Company.) * Fig. 7.

FIG. 6—FIXED COHERER TYPE OF M. P. LIGHTNING ARRESTER FOR ALTERNATING-CURRENT OR DIRECT-CURRENT CIRCUITS.—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

2. *(b)* Metal multi-gap with resistance in series. (General Electric Company.)

The construction of this well-known unit is clear from Fig. 8. It consists essentially of air gaps formed between metal balls (brass in practice) in series with a non-inductive resistance which

*See *The Electric Club Journal,* Vol. II., pp. 30, 31, 34, 35.

the inventor so proportioned as to freely radiate the heat due to the passage of current and thus by keeping the cylinders cool it is designed to prevent the formation of conducting gases in the air gap, which otherwise would not allow the arc to break.

2. *(c)* Metal multi-gaps with diverging sides. (*S K C* system, Stanley Electric Company.)

The principle of this device is shown in Fig. 9. It consists of a nest of concentric cylinders of brass or other high melting-point metal with flaring upper ends. The line terminal is at the center of this group, the ground connection at the outside. (Fig. 10

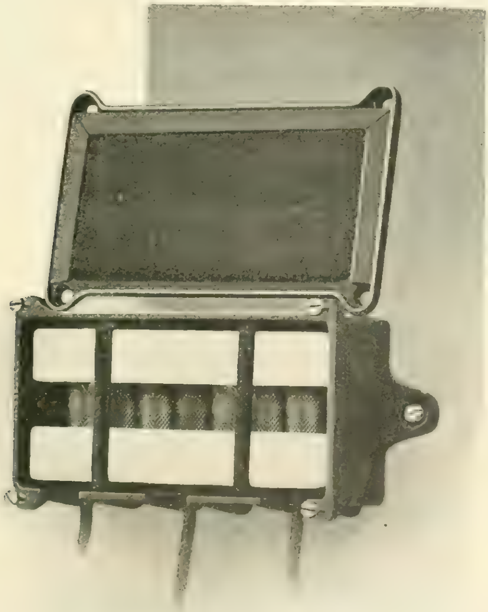


FIG. 7—NON-ARCING METAL AND MULTI-GAP TYPE OF LIGHTNING ARRESTER FOR ALTERNATING-CURRENT CIRCUITS.—WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

shows two of these with a common connection between for protecting a single-phase circuit.)

When line current follows the static discharge, it takes the narrowest gap space of the arrester; at the same time a current of air is established through the many small holes in the bottom and top-

supporting porcelains. This draft pushes the arc upwards, when by reason of the attenuation of the arc and the greater cooling surface of these gaps the short-circuit is broken.

FIG. 8—METAL MULTI-GAP TYPE OF LIGHTNING ARRESTER WITH RESISTANCE, FOR ALTERNATING-CURRENT CIRCUITS OF 2 000 VOLTS, DOUBLE POLE. — GENERAL ELECTRIC COMPANY

3. *(a)* Coherer, loose *(S K C System.)* Fig. 11 shows a glass tube mounted on a suitable support, filled with a number of fine shot-like (oxidized metal) particles which by reason of being in bad electrical contact with one another practically open the circuit for ordinary voltages, and yet pass high tension discharges. The resistance of the particles and the many contacts are depended on to suppress the short-circuit. A tube 18 inches long filled with such metallic particles is claimed to pass but little current with as much as 2,000 volts applied at the terminals.

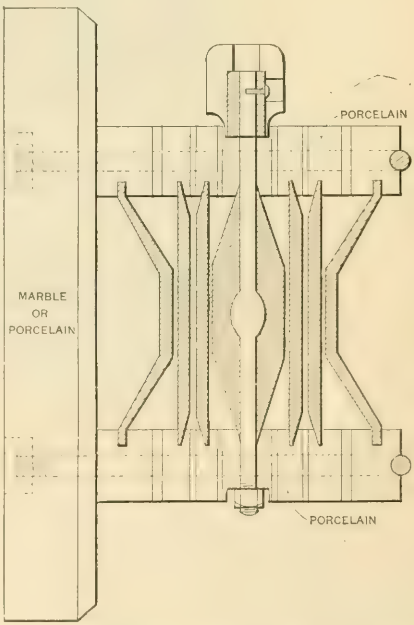


FIG. 9—METAL MULTI-GAP TYPE OF LIGHTNING ARRESTER WITH DIVERGING SIDES SHOWING CROSS SECTION OF LIGHTNING ARRESTER UNIT.—STANLEY ELECTRIC COMPANY

The number of these tubes required depends upon the voltage. As an extra precaution against grounding the line, they are placed in series with an adjustable air gap.

A special modification of this unit is employed for direct-current circuits.

3. *(b)* Coherer, fixed. (Westinghouse Electric & Mfg. Company.)

M. P. Arrester. At

present rated for 1 000 volts, alternating current or direct current. See above.

Although the ground may be conveniently considered the last part of the discharge path to operate during a static disturbance, it is of first importance in a successful layout. The local geological conditions materially affect this element of a system of protection so that each case requires special consideration. Where it is desired to make certain of a good ground the following method is recommended:

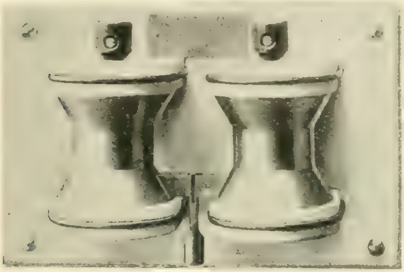


FIG. 10—METAL MULTI-GAP TYPE OF LIGHTNING ARRESTER WITH DIVERGING SIDES, SHOWING DOUBLE POLE UNIT FOR 1 000 TO 1 200 VOLTS.—STANLEY ELECTRIC COMPANY

"Too much importance cannot be attached to the making of proper connections —short and straight as possible from the arrester to ground.

Good ground connections may be made in the following manner:

First, dig a hole four feet square directly under the arrester until permanently damp earth has been reached.

Second, cover the bottom of this hole with crushed charcoal (about pea size).

Third, over this lay ten square feet of tinned copper plate.

FIG. 11—LOOSE COHERER TYPE OF LIGHTNING ARRESTER SHOWING UNIT OF LINE DISCHARGER.—STANLEY ELECTRIC COMPANY

Fourth, solder the ground wire, preferably No. 0 copper, securely across the entire surface of the ground plate.

Fifth, cover the ground plate with crushed charcoal.

Sixth, fill the hole with earth, using running water to settle.

This simple method of making a ground connection has been found to give excellent results, and yet, if not made in proper soil, will prove of little value. Where a mountain stream is conveni-

ently near, it is not uncommon to throw the ground plate into the bed of the stream. This, however, makes a poor ground connection, owing to the high resistance of pure water and the rocky bottom of the stream. Clay, even when wet, rock, sand, gravel, dry earth and pure water are not suitable materials in which to bury the ground plate of a bank of lightning arresters. Rich soil is best. Where permanent dampness cannot be reached, it is recommended that water be supplied to the ground through a pipe from some convenient source.

Where possible, a direct connection to an underground pipe system, especially to a town or city water main, furnishes an excellent ground, on account of the great surface contact with the earth and the numerous alternative paths for the discharge. In a water power plant the ground should always include a connection to the pipe line or penstock."

MODERN PRACTICE IN SWITCHBOARD DESIGN

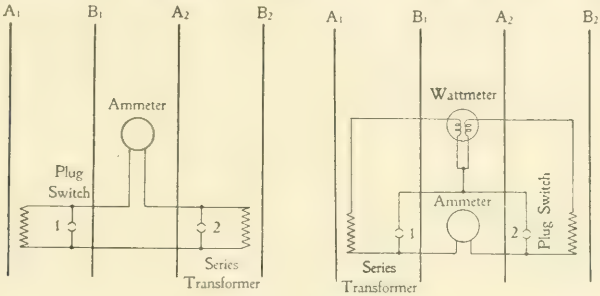
PART VI—HIGH TENSION SWITCHBOARDS, HAND CONTROLLED

By H. W. PECK

IN direct-current practice there are three standard voltages, 125, 250 and 600 volts. In alternating-current practice, there is a much greater range which is generally divided into three main classes, low tension, high tension and extra high tension. Each of these is in turn subdivided as practice has made necessary. In the low tension class 110, 220, and 440 volts are standard for generating apparatus; 100, 200, and 400 volts for translating apparatus. In the high tension class, 1 100, 2 200, 3 300, 6 600, 11 000 and 13 200 volts are standard for generating apparatus and 1 000, 2 000, 3 000, 6 000, 10 000 and 12 000 volts for translating apparatus. The highest pressure for which standard generators are wound is 13 200 volts. In the extra high tension class, therefore, we have standard voltages for transmitting apparatus of 22 000, 33 000, 44 000, 66 000, and 88 000 volts with corresponding receiving apparatus for 20 000, 30 000, 40 000, 60,000 and 80 000 volts.

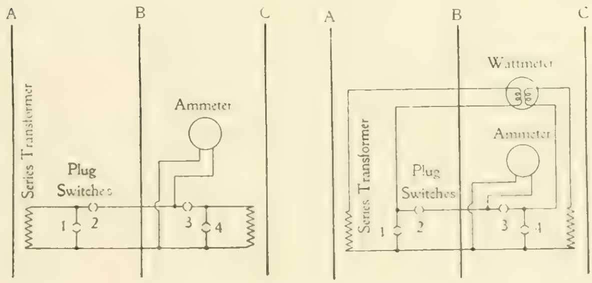
Practically all high tension power is generated at 25 cycles as that is the lowest frequency which can be used commercially for

lighting and yet it is low enough to give satisfactory results for transmission and the operation of motors. Low tension plants used mostly for lighting, generally have a frequency of 60 cycles. Other frequencies are not uncommon but are generally selected to agree with an old installation or for some quite special reason. Alternating-current equipments of the high tension class are more commonly installed than are those of the low tension class. The



TWO-PHASE CIRCUITS

To Read Phase A; Plug 1 is out, 2 is in
To Read Phase B; Plug 2 is out, 1 is in



THREE-PHASE CIRCUITS

To Read Phase A; Plugs 1 and 3 are out, 2 and 4 are in
To Read Phase B; Plugs 1 and 4 are out, 2 and 3 are in
To Read Phase C; Plugs 2 and 4 are out, 1 and 3 are in

FIG. 22.

control of the circuits at these pressures and the insulation of the apparatus both for its own protection from grounding or short circuiting and for the protection of the operator, requires apparatus of different design from that used on the low pressure direct and alternating current equipments already described.

OIL SWITCHES.

The switches and circuit breakers are of the oil type, which has proved smaller, cheaper, and in general more satisfactory for high

voltages than any other type of switch. They are designed for various capacities and for the different voltages mentioned above except that in certain cases one design serves for two or more of these standard pressures. They may be mounted either on the back of the switchboard or separately at a distance from the board. In both cases the contacts are away from the front of the board in a position where they are not liable to be injured. Leaving auxiliary operated switches for later consideration, the hand operated type is controlled by a handle projecting through the panel, in the first case operating the switch direct; in the second case operating it through bell cranks and rods. By this method the switch may be in almost any position relative to the board if not at too great a distance.

INSTRUMENTS

TRANSFORMER—The meters of high-tension equipments are operated from the secondaries of series or current transformers and shunt or potential transformers. These are designed so that the secondary current or potential is the same for all transformers with the rated conditions in the primary. Five amperes is the standard secondary current of all series transformers, and 100 volts is the standard secondary pressure for all shunt transformers. They are designed to have a very accurate ratio throughout their range and every transformer is carefully tested.

The shunt transformers are compensated to give the correct ratio at the rated load and should have this load for the most accurate measurements. Series transformers are compensated for the losses at a given current but they become less accurate through their range as the resistance in the secondary is increased or the power-factor decreased. Series transformers therefore should be loaded as lightly and with as little inductance as possible.

The secondary of an instrument transformer should always be grounded so as to eliminate the danger from a breakdown of the insulation between the primary and the secondary. This further removes the operator from danger at the front of the board. The transformers are located at any place convenient to the main wiring; on the back or frame work of the panels when the switches are mounted on the switchboard; at any suitable place near the switches when they are separately mounted. In the latter case only the low tension secondary leads are brought to the switchboard proper. The meters are all designed with five-ampere current coils and 100-volt shunt coils and are calibrated with the desired scales from

standard transformers so that they may be used with any transformer of the proper ratio.

In direct-current practice one ammeter in each important circuit, two voltmeters, and frequently a recording wattmeter used to register the total power delivered by the station, comprise the usual complement of instruments. The practice is much the same in small alternating-current installations where refinements of operation are of small importance and the initial cost must be kept as low as possible. It has been found necessary, however, in power plants of considerable size to use various other meters in order to secure economical and satisfactory service.

Ammeter—Ammeters are usually supplied for every main circuit, generator and feeder. If the load is always balanced, one ammeter in each circuit is sufficient. If it is not balanced, the current in each phase should be indicated by a separate ammeter or an equivalent arrangement of one meter and several plug switches. The method of using these switches to cause the meter to indicate the current in any desired phase is shown in Fig. 22. As a dangerously high potential will occur across the secondary terminals of a series transformer if open-circuited, these switches are arranged not only to connect the meter in proper circuits, but also to short-circuit the other transformers when not in the circuit with the meter. This arrangement is cheaper and takes less space than the two or three meters otherwise required and is entirely satisfactory for use in checking the condition of a steady current which may be expected ordinarily to be balanced. It is of little value, however, on a rapidly fluctuating load. The wattmeter can be connected in, as shown, so that it will read continuously regardless of the manipulation of the plugs.

Voltmeter—Voltmeters are used in the same manner as in direct-current practice, one of the bus bars or each set of bus bars, and one which can be connected by means of a plug to any other desired circuit. The plug receptacles are usually six point for two-phase and eight point for three-phase circuits, as shown in Fig. 17, Vol. II, p. 310, so that the pressure across any phase can be measured. The plug receptacles are always connected in the low tension side of the shunt transformer.

Wattmeter—As the true energy of an alternating-current circuit cannot be determined from the ammeter and voltmeter readings, an indicating wattmeter is often necessary. This meter is generally used in the generator circuits as the operator should know

the size of the load that is being carried by the generator and its prime mover as well as the current that the generator is delivering. In connection with a feeder, however, the amount of power is of less importance to the operator than is the amount of current being delivered over the line, as the loss in the line depends upon the current rather than the power transmitted. Only one wattmeter is required for each circuit as it is designed for polyphase as well as for single-phase use. Within small limits of accuracy they measure the true power with any power-factor.

Integrating wattmeters also are designed for use on either single-phase or polyphase circuits to record the true power. Commercially, they are the most important meters of an equipment and should be installed with extreme care. Their record shows the amount of power delivered to customers when sold by meter or shows the amount used in various ways by the generating company and enables the cost to be computed and economies to be worked out. They should be used very nearly as free as ammeters. They should afford a record of the total kilowatt-hours of the generators and a check record of the total kilowatt-hours taken by the feeders. Oftentimes the power for several small feeders may be measured by one wattmeter.

Power-Factor Meter—The power-factor meter is the instrument that is the next in importance to those mentioned above. It is designed for single-phase and polyphase circuits. Its usefulness in the generator circuits has already been explained. It is used similarly in circuits to rotary converters and synchronous motors as the power-factor of these machines can be controlled by regulating their field strengths and it is of sufficient importance to run them at unit power-factor to warrant the installation of a power-factor meter. They are often connected in the feeder circuits, so that the main operator can check the operation of the sub-stations and regulate them so as to counter-balance the reactance of the transmission line and any other load which may be upon the feeder. Where synchronizing is to be done with the hand operated switches, a synchroscope should be provided. The use of lamps to indicate synchronism is a crude method. It is slow, inaccurate and dangerous.

A synchroscope shows continuously, when plugged in the circuit, whether the entering machine is running too fast or too slow and how much the speed is in error. It indicates the exact moment of synchronism and the rate of approach so that the operator can get

the switch closed just at the right moment even if there is considerable difference in speed between the machines. A polyphase synchroscope is made, but the single-phase instrument serves just as well and the connections are more simple. The latter is therefore more commonly used.

FREQUENCY METERS—Although alternating-current apparatus will operate with good satisfaction through a considerable range in frequency, the refinement of operation requires that it be used very near the frequency for which it is designed. In every generating station there should be the means of readily determining the frequency. This may be done by counting the revolutions of the generator or measuring them with a tachometer but it is much more simple to make the measurement electrically by means of a frequency meter and have before the operator a constant indication of the frequency.

It is often valuable and sometimes commercially necessary to have a continuous record of the electrical conditions of a circuit. For this purpose, curve drawing instruments of all the kinds described above except of course the synchroscope, are used.

FACTORY TESTING OF ELECTRICAL MACHINERY—XVII

By R. E. WORKMAN

INDUCTION MOTORS Continued

EXPERIMENTAL TESTS

The tests made on induction motors in many respects are very different from those made on direct-current motors and yet practically the same determination—iron loss, copper loss, efficiency and torque characteristics, are obtained.

The following tests are usually made in the order given:

(1) Measurement of resistance.
(2) Running saturation.
(3) Open circuit saturation.
(4) Locked saturation.
(5) Power curve (a) By brake test.
(b) By losses.
(c) By losses with the aid of a diagram.*

*See "Application of Alternating-Current Diagrams—The Heyland Diagram," *The Electric Club Journal,* Vol. I., p. 658, and Vol. II., p. 118; also "A Practical Vector Diagram for Induction Motors," by H. C. Specht. *The Electrical World and Engineer,* Vol XLV., p. 388.

(1) Resistance Tests —The resistances are measured from terminal to terminal of the motor as in the case of alternating-current generators.

(2) Running Saturation —The running saturation curves are those of amperes and watts plotted to terminal voltage, the motor running without load, and the voltage being varied between wide limits.

The ampere curve corresponds to the saturation curve of a direct or alternating-current generator, representing the magnetizing current for different terminal voltages, at no-load.

The watt curve is a curve of iron loss plus friction plotted to the terminal volts.

Preparations for Test—The motor is connected to the load terminals of the table. The power is applied to the other terminals of the table, so that the current in each phase, and the voltages between terminals may be measured. In all cases a two-phase machine has its phases connected across the terminals 1 and 3 and 2 and 4 respectively, and a three-phase machine has its phases connected to the terminals 1, 2, and 3. A dynamometer and a wattmeter of suitable current-carrying capacity are connected on the table as shown in Fig. 74. The readings are taken, starting with a voltage about 20 per cent. over the rated voltage of the motor. The voltage of the circuit is varied by rheostats in the generator field circuit placed near or under the table. The generator speed is brought very close to the correct value for the desired frequency and is checked occasionally throughout the test.

Conduct of Test—The motor is started up on a voltage somewhat below the rated voltage, depending on the size of the machine. Machines up to 20 hp with squirrel cage secondaries may be started on full voltage, but large machines, and especially those with low resistance secondaries should be started on one-half voltage or lower. The voltage is then brought up to about 20 per cent. above its normal value and simultaneous readings of watts, amperes and volts are taken. The voltage should be decreased gradually between steps and time enough allowed for the motor to adapt itself to each new voltage before the readings are taken. This is especially important toward the lower voltages and with large machines. The instruments are changed from phase to phase in the manner described under alternating-current generators in Vol. I, p. 617.

Precautions to be Observed—It is important that the generator speed or the frequency of the supply circuit should be within about one per cent. of the correct value throughout.

It will as a rule be found impossible to obtain a steady deflection on the wattmeter in this test, the needle continually swinging to and fro; hence, it is necessary to judge the amount of a reading from a mean between the maximum and the minimum readings on the wattmeter scale. Do not take the reading which is geometrically equidistant between the maximum and minimum swings, since the scale of a wattmeter is generally not uniform.

In case the readings suddenly increase about half way down the curve, or at any time show a marked change, the trouble is very apt to be with the bearings. Tight bearings, end thrust, or failure of oil rings to operate properly, will make large errors in the readings, even though the mechanical trouble be slight.

Working up Results—In order to find the current corresponding to a dynamometer reading, the square root of the reading must be multiplied by the constant of the dynamometer. The total current, i. e., the current which, when multiplied by the terminal voltage gives the apparent input, is found by multiplying the average of the currents in the phases by $\sqrt{3}$ in the case of a three-phase machine; and by 2 in the case of a two-phase machine; which involves the assumption that the phases are quite closely balanced.

The wattmeter readings in the case of three-phase measurements are taken under the following conditions:

(1) With the current coil of the wattmeter in phase 1 and the voltage coil between phases 1 and 3.

(2) With the current coil in phase 2 and the voltage coil between phases 2 and 3.

The algebraic sum of these two readings gives the total watts.

Where the power-factor is below 50 per cent. one of these readings will be negative and should be subtracted from the other. It will be known when one reading is negative, as the voltage leads of the wattmeter will then need to be reversed between the two readings. In the case of two-phase measurements, whether the two phases are independently wound or not, the power is found by adding the wattmeter readings of each phase. These readings should be equal. If by reason of a

slight inequality in the voltages, or for some other reason, the two wattmeter readings are not equal, the sum will still give the total power applied, though it will be well to investigate the unbalancing—the cause may be an error in the motor winding. An unbalancing of the voltage of one or two per cent. will unbalance the amperes and watts from 10 to 30 per cent. in different motors. It is therefore very probable that the inherent slight differences between two similar transformers furnishing two-phase power and a similar slight difference in the motor windings would produce quite a large unbalancing when the motor is running with no load. This is not so marked when the motor is loaded.

Fig. 82 shows the running saturation curves for a 5-hp two-phase, 220-volt, 60-cycle, 8-pole induction motor with a squirrel cage secondary. When the motor has a wound secondary with the terminals carried to slip rings, this test is made with the secondary short-circuited through another polyphase table This current is usually much less than the corresponding primary current. If the secondaries are cage-wound it is well to check the resistance of the end rings with that called for on the specification sheet. Different types of end rings are generally stamped in some way to indicate their relative resistance. An error in the resistance of the end rings will not affect the running saturation curves but will affect the locked saturation curves and the power curves. The detection of an error of this nature as soon as the motor is put on test will often save much trouble.

(3) Open-Circuit Saturation—This test, which can be made only on motors with wound secondaries, is made in order to check the e. m. f. induced in the secondary when a given voltage is applied to the primary terminals and also as a check on the iron loss determined from the running saturation. It is taken in exactly the same way as the running saturation, except that the secondary being open, the motor will not run. The voltage across the slip rings of the secondary is taken in addition to the other readings.

(4) Locked Saturation—This test is made, first, to measure the starting torque of the motor at different voltages and, second, to calculate the effect of magnetic leakage in reducing the power-factor of the motor. The starting torque is measured by means of a brake and a pair of scales and the leakage calculation, described later, is made from the readings of volts, amperes and watts.

Preparations for Test—The brake arm, pulley, scales, etc., are set up as described for direct-current motors. The motor is connected up as for running saturation, and instruments of a capacity found by trial or by previous experience, to be suitable, are connected on the table.

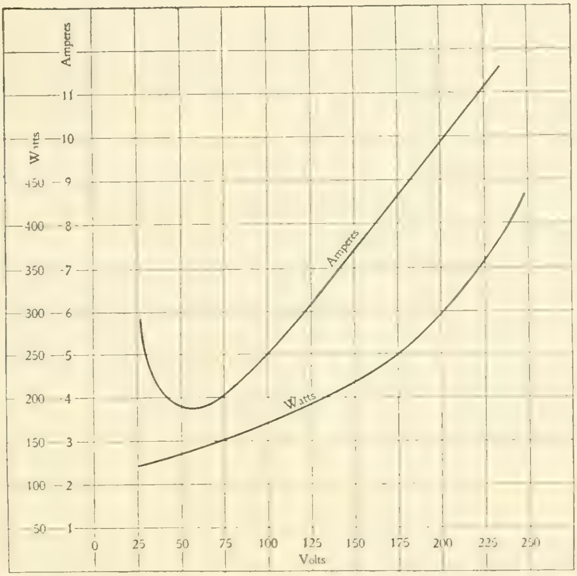


FIG. 82—RUNNING SATURATION CURVE OF A 200 VOLT, 60 CYCLE, EIGHT POLE, FIVE HP, TWO-PHASE INDUCTION MOTOR

Conduct of Test—A low voltage is first applied to the motor with the brake loose to see that it runs in the proper direction. Before starting it is important to make sure that the brake is loose on the pulley. Then the outer end of the brake should be held down while the motor is started. This may avoid serious accidents, if the motor should start in the wrong direction. The circuit is then broken and the brake screwed up tightly so as to prevent the rotating part from turning. A low voltage is again applied to the motor terminals and a rough reading of the current taken. From this the current that will be required on full voltage can be closely approximated and the proper dynamometer and wattmeter selected. The torque and the watts may be assumed to vary as the square of the voltage, and the current to vary directly as the voltage. If the source of power will stand the strain, the locked readings should be taken at full voltage and

decreased to something less than quarter voltage, taking about five points. The readings taken are: volts, amperes, watts and torque, the volts being reduced stepwise between readings. For small motors a spring balance is sometimes used, instead of the scales, as it can be more quickly read and is practically self-adjusting. All readings should be taken when the voltage is steady at or near the value desired, the exact voltage being read.

Usually two mechanical forces oppose the rotation of the secondary, viz: The pressure on the scale platform and the friction of the motor bearings. This bearing friction is an extremely variable quantity and difficult to eliminate. It is not the same for all impressed voltages on account of the vibration of the machine. For the higher voltages the vibration is greater and the frictional torque is therefore less, in fact for voltages above 50 per cent. of the normal voltage of the motor the effect of the bearing friction may be neglected. This is especially true in the case of large motors, and it may be added that the readings at the high voltage points are of much greater importance, those at the very low voltage points being relatively of little use in after calculations.

EDITORIAL COMMENT

The Electric Journal

With this issue THE ELECTRIC CLUB JOURNAL becomes THE ELECTRIC JOURNAL, "a Journal of Engineering and a Journal of Inspiration."

The JOURNAL has developed. It is not now merely a record of the proceedings of The Electric Club. It draws its material almost entirely from original sources. Its circulation has constantly increased until the club membership is a very small per cent. of its subscription list. It has in reality become an *electric journal* in a broad sense, and it now becomes THE ELECTRIC JOURNAL in name as well as in fact.

The aim in editorial policy will continue. The JOURNAL will deal with the principles and operation of apparatus rather than speculative theory and formulæ, and it will draw from the actual experience rather than from the imagination of its writers. It will deal with the engineer himself as well as the results which he accomplishes.

The JOURNAL is particularly fortunate in receiving the cordial support of a large body of capable engineers in active work, including general engineers, constructors, designers and operators. Many of these men write but little, but when they write they tell what they are actually doing. The material from this source has in the past given the JOURNAL its strength, and it will continue to do so in the future.

The ELECTRIC JOURNAL is to be a JOURNAL for the PROGRESSIVE ENGINEER, be he young or old.

American Institute of Electrical Engineers

In the past five elections the American Institute of Electrical Engineers has chosen three of its presidents from electrical manufacturing companies. At the last election Dr. Schuyler Skaats Wheeler was elected by the largest vote ever given a candidate for president by the members of the Institute. Dr. Wheeler has been active in Institute affairs. His donation of the Latimer Clark Library was the foundation of the library of the Institute. He has been an active representative of the Institute on the committee which has in hand the engineering building under the Carnegie gift. When Mr. Steinmetz of the General Electric Company became president the Institute had 1269 members. A new era of activity

was begun during this administration, which continued under the subsequent administrations of Scott of the Westinghouse Electric & Manufacturing Company, Arnold, an active consulting engineer, and Lieb, a leading operating engineer. The membership is now 3460. The interests of the Institute promise a continued development under the leadership of Dr. Wheeler, president of the Crocker-Wheeler Company.

Success in Electrical Engineering

"I consider it a matter of minor consequence if a young man is prevented from completing his college course provided he has learned two things:

"First, How to think, and

"Second, How to apply what he knows."

Such was the sentiment expressed in a recent conversation on educational matters by the vice president of one of our leading railroads.

The two elements which are designated as the conditions of success are especially essential to the electrical engineer.

We are often struck by the differences between men. A class graduates. Its members have had the same training, and many appear of fairly equal ability. But in a dozen years some may be eminently successful, many will be fair routine men, others cannot be found. They start with equal prospects, but some saturate more quickly than others; some are able enough but they accomplish little because they never get into right relations with their work and their fellows.

Has not our railroad philosopher put the matter in a nutshell? Do not many fail because they have failed to learn the two things he specifies?

Why have they not learned them? Sometimes courses are too narrow and exclusively technical, or teachers are more apt in imparting information than in directing development. But the fault lies largely with the individual. He and he alone can correct it. If he is to be active rather than passive, if he is to handle his mind (to think) and to use what he knows, if he is to have initiative, to increase by development from within, rather than by accretion of formulæ and facts from without, it must come through his own effort. He must get the right point of view.* He must study himself.

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*See "The Point of View"—Walter C. Kerr, *The Electric Club Journal,* December, 1904.

The usefulness of a man—be he mechanic or teacher, physician, engineer or preacher—depends upon what he accomplishes.

A man is, therefore a machine for doing work. It is his business to find out how to run the machine to get maximum efficient results. He must find the kind of work he can do best and the method which will produce the best output. He should learn the points of friction and lubricate them. He should determine the conditions of maximum efficiency and the overload which causes inferior output and permanent injury. Let him give to himself—physically and mentally—the same sort of study and care that an enthusiast gives to his automobile. Both are complicated machines for doing something. The results depend upon intelligent care and proper manipulation. Sometimes the high gear is wanted and sometimes the low gear. Success in both depends upon a good practical understanding of what the machine can do, followed by vigor and common sense in directing it.

CHAS. F. SCOTT

International Railway Congress

Pittsburg rarely has visitors more distinguished or more representative of the world at large than the members of the International Railway Congress, who visited Pittsburg on their way west from the Washington meeting. The members had an excellent opportunity to view the terminal facilities of the various roads centering in Pittsburg, which, by the way, have an annual railway tonnage of 76 000 000 tons, which is probably several times that of any other district of similar area in the world.

The special trains brought the party to the Westinghouse works and to the Homestead steel works. At the Westinghouse works a luncheon was given to the visitors and local guests, the total numbering 700. The visitors were greatly interested in the methods of handling freight, in the large output of the Homestead mills in which relatively few men are employed, and electric motors are largely used; also in the new development in friction buffers and new air brake appliances for the operation of freight trains.

Single-Phase Locomotive

It is probable, however, that nothing more significant of future development in railway work was observed than the operation of the new single-phase locomotive. The single-phase locomotive in tests in the presence of the visitors handled a train nearly half a mile long more easily and accelerated it more rapidly than a heavy steam locomotive could do. The multiple unit system gives a flexibility

in the electric locomotive which is not found in the steam locomotive. When two steam locomotives are combined there must be two independent engineers and two independent firemen. The electric locomotive, however, can consist of different units, which combined together operate as a single locomotive under the control of a single operating handle. The 135-ton single-phase locomotive which was exhibited before the Railway Congress can be operated either as a whole or as two independent units.

The first single-phase electric locomotive exhibited to railway officials begins in its capacity and in weight on drivers and in drawbar pull, a step beyond what has been secured in the ordinary steam locomotive for heavy freight service after the steam locomotive has had nearly a century of development. It has met mechanical limitations which are not encountered by the electric locomotive.

PERSONAL MENTION

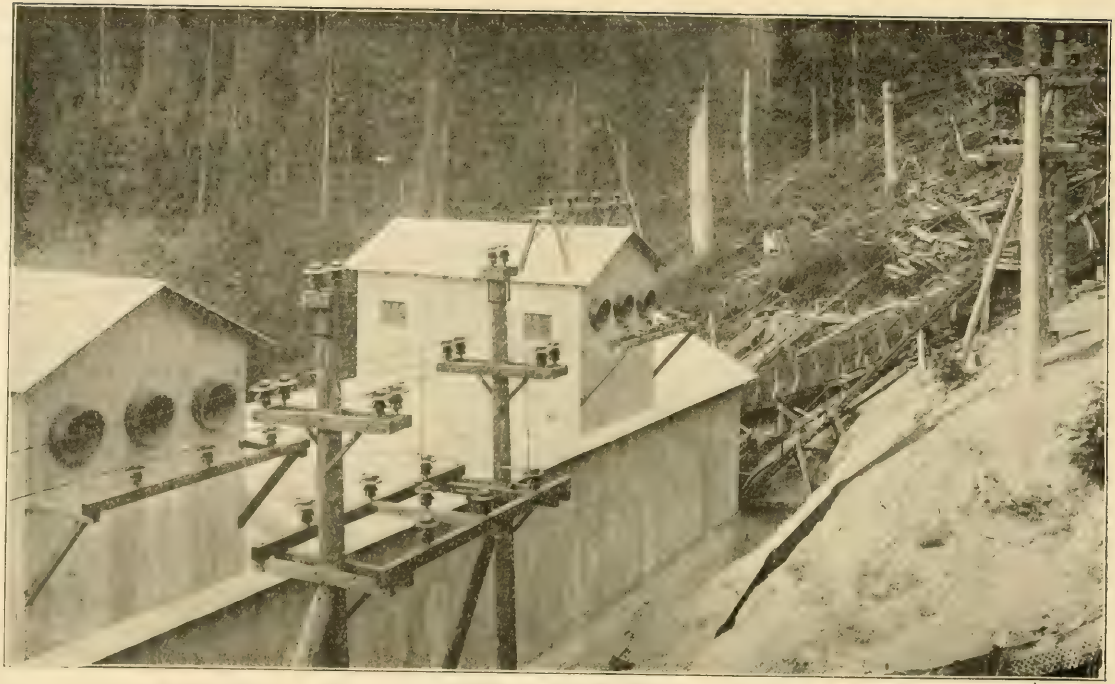
Mr. E. M. Herr has been made first vice president of the Westinghouse Electric & Manufacturing Company. This office has been vacant since the resignation of Mr. Bannister several years ago. Mr. Herr has been primarily a railroad man. After graduation at Yale and an apprenticeship in railway shops he was connected with various roads in different positions, principally with their motive power departments. He was connected with the Chicago, Milwaukee & St. Paul, the Chicago & Northwestern, the Burlington, and was superintendent of motive power of the Northern Pacific until seven years ago, when he became an officer of the Westinghouse Air Brake Co., of which he has been vice president and general manager. He has a familiarity with electrical matters, as he was superintendent of telegraphs of one railway with which he was connected and was also general manager of the Gibbs Electric Co.

Mr. Herr's intimate connection with the Air Brake company with its three thousand employes and his well known success as manager of that company attests his fitness for his present relationship to an electrical manufacturing company.

Mr. W. S. Heger, manager of the San Francisco office, has resigned his position and severed a long connection with the Electric company.

Mr. W. W. Briggs has been appointed acting manager of the San Francisco office of the Electric company and will have charge of all business connected with that territory.

Mr. H. E. Blatch, formerly an apprentice of the Electric company, is now in the correspondence department of the Canadian Westinghouse Company, Ltd., Quebec, Canada.



THE POWER STATION OF THE PUYALLUP WATER POWER COMPANY, SEATTLE, WASH.

The high tension wires enter the power house through large terra cotta pipes, resembling joints of sewer tile. These pipes are 12 inches in diameter and are inclined outward. A further modification of this method provides against the entrance of birds by placing a glass plate over the outer end of the pipe. This glass plate is drilled to accommodate the conductor.

This construction was recommended by Mr. C. E. Skinner at the annual convention of the American Institute of Electrical Engineers in 1903 for voltages up to 30 000. In several instances 50 000 volts have been carried into a power station through ordinary sewer tile with very satisfactory results. Local climatic conditions necessarily determine to a large degree, the choice of a suitable method.—Ed.

THE

ELECTRIC JOURNAL

VOL. II JULY, 1905 No. 7

THE MERCURY VAPOR CONVERTER*

P. H. THOMAS

Chief Electrician Cooper Hewitt Electric Company

THE motor-generator set or the rotary converter has, broadly speaking, long been the only practical commercial apparatus for the conversion of alternating current to direct current. In large units, and when operating from polyphase circuits, this is a very satisfactory equipment, but the small single-phase motor-generator set is altogether an unsatisfactory piece of apparatus. It is largely used to charge small storage batteries and often has to be placed in private automobile houses where the attendant is not competent.

As a substitute for such apparatus the mercury vapor converter finds a great field, for not only is it more efficient than a motor-generator set of similar size but it has practically no moving parts, and may be made to start with the simple closing of the main switches so that it is self-starting in case the power goes off. The development of the vapor converter has been most rapid and though it undoubtedly will have many improvements in form, it is a commercial success, being on the market in various sizes up to 30 amperes.

The operation is as follows:

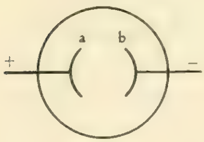


FIG. I

Let Fig. 1 represent a vacuum tube or globe filled with mercury vapor and provided with two electrodes. In order to establish a current across this gap, it is necessary to raise the potential to a very high value, perhaps 25 000 volts, but after the current is once established 10 to 14 volts is sufficient to maintain it. This high starting potential is practically all due to a peculiar resistance

*An experimental lecture before The Electric Club, April, 28, 1905.

offered between the mercury vapor and the surface of the negative electrode. As soon as the current is established this particular potential drops to about four volts. The total running potential is made up about as follows: Four volts between the positive electrode and the mercury vapor, two to six volts through the mercury vapor and four volts between the mercury vapor and the negative electrode. If we have a long thin tube like a lamp, the potential through the vapor is much higher and may be as high as 70 volts. The potential at the positive electrode and that through the mercury vapor are approximately the same for both starting and running.

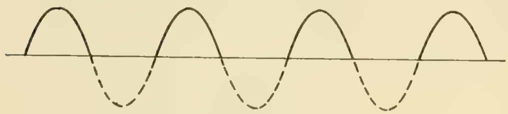


FIG. 2

If once the current flow ceases even for an instant the negative electrode resistance is established and the high starting potential must again be applied. It is one of the remarkable characteristics of this apparatus that, though the period of zero current is but momentary, it is quite sufficient for the high resistance of the negative electrode to establish itself. It has been estimated that this can occur in one millionth part of a second.

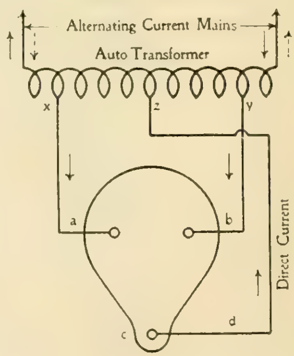


FIG. 3

Thus if the apparatus is supplied with direct current it will operate continuously on a low voltage after it is once started. If, however, it is supplied with alternating current, the high starting voltage will have to be applied at each alternation and obviously at alternate electrodes, since they will change their signs with each alternation.

If now some means of breaking down this high potential is permanently applied to one electrode, as *b*, Fig 1, and alternating-current is applied, it is evident that the current will flow through the apparatus only in one direction, from *a* to *b*, since there will be now no electrode resistance at *b*, whether *b* is positive or negative, but there will be resistance at *a* every time *a* is negative. This resultant current will be intermittent, half of each cycle being dropped as indicated in Fig. 2.

If the globe be provided with three electrodes connected to an

auto-transformer as shown in Fig. 3, both alternations may be made to act in the wire *d* in the same direction. The direct current produced in this wire is still a pulsating one, but the zero period is reduced to a single instant as shown in Fig. 4.

In Fig. 3 the electrode *c* is provided with the means mentioned above (to be described later) for breaking down the high negative electrode resistance at all times. The operation is as follows: For one-half cycle, the current flows from *x* to *a* through the mercury vapor to *c*, to *z* and back to *x* and *y*. During the second half cycle the flow is from *y* to *b*, through the mercury vapor to *c*, to *z* and back to *y* and *x*. A circuit cannot be established between *a* and *b* in either direction since one or the other is always negative and therefore it would require the 25 000 volts to start a current either way through this path. The line *cz* contains the direct-current apparatus to which the converter is to supply power and will carry a pulsating current as indicated in Fig. 4.

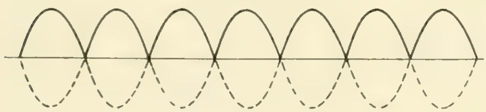


FIG. 4

Fig. 5 represents one method of continuously breaking down the high resistance at *c*. The small battery *P* is so placed as to send its current as indicated in the figure. When current flows from the battery the electrode *c* will remain open to all currents from *a* and *b*, while *a* and *b* are always open to ingoing currents and always closed to outgoing currents. The initial starting of the battery current is easily accomplished by tilting the globe backward and forward, allowing the liquid mercury to flow over the ridge between *M* and *N* thus making a momentary metallic circuit. As soon as this mercury bridge is broken, the current is transferred to the vapor without there being an opportunity for the negative electrode resistance to be established.

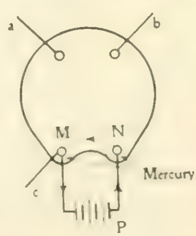


FIG. 5

If polyphase current is used with a similar apparatus, the battery is unnecessary since at no instant will all the legs of the polyphase circuit be zero; thus the flow of current never ceases. The connections are shown in Fig. 6. As before, operation is started by applying either alternating current or direct current between *M* and *N* and rocking the globe causing the liquid mercury to flow between these points breaking down the high potential at

M. For example, suppose that at the instant the resistance *M* is broken down, the potential at *a* is just rising from zero, current will flow from *a* to *M*. 120 degrees later current starts from *b* to *M*. 120 degrees after this current starts from *c* to *M*. In the meantime the current in *a* has gone through the cycle. Before the current in *c* reaches zero, the current in *a* has started on its second cycle, and so on, so that at any instant there is current passing into *M* and the resultant current in the power line *MO* is as shown dotted in Fig. 7.

This practically solves the problem of a continuously operating converter for polyphase currents, but the many private automobile stables in the resident districts, which are reached only by single-phase alternating current, as well as many other considerations, create a demand for a single-phase self-starting converter. Such a converter has been constructed, and as previously stated, is actually in commercial use in sizes up to 30 amperes. To understand the principle of operation refer to Figs. 3 and 4, where it will be noted that the period of zero current is of an instant's duration, but that at each zero point the 25 000 volts must be applied. If, however, these current waves could be made to overlap even a very slight amount, as shown in Fig. 8, the converter would operate continuously. This is accomplished by inserting a reactance coil in the line *cz*, Fig. 3, which causes a slight lagging in the currents and makes them to overlap as shown in Fig. 8. For example, the current from *a* does not become zero until the current has been established in *c* by the rising voltage in *b*. The resultant current in line wire *d* is shown by dotted lines in Fig. 8. This is, of course, a fluctuating current, but with sufficient reactance in the circuit *d* and possibly some reactance or resistance in the main line to give backing, the converter will operate continuously without *going out*.

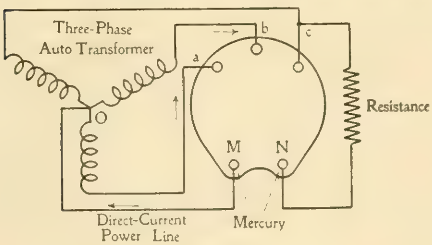


FIG. 6

The commercial form of the apparatus is shown in the following illustrations. By means of small electromagnetic devices, the converter is made self-starting with the throwing in of the main switches. The bulb is made of glass and mounted on suitable knife edge trunions so that on

starting it may be easily tilted, causing the liquid mercury to flow between the two liquid electrodes located in the bottom of the bulb. As soon as the operation is established, the tilting mechanism is automatically switched out. The choke coil or sustaining coil is seen below the frame; the variable choke coil used as a regulator may be seen behind the panel with its operating handle passing through the panel. This coil is connected directly in the supply mains.

The apparatus is in no sense a transformer. It does not convert energy from one form to another. Its action is simply that of a set of valves opening and closing gateways and thus allowing currents of one direction to flow through a given line.

About 15 volts are lost in the vacuum for all currents. The

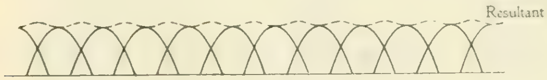


FIG. 7

losses in the auxiliary apparatus, choke coil, transformer, etc., may be calculated as those in any design of similar apparatus.

The influence of the character of the load upon the design and operation of the sustaining coil (that is the choke coil which keeps the converter alive) is quite marked. When supplying current on a resistance load it is evident that whatever the drop in the supply voltage, provided the remainder is greater than the 15 volts which are lost in the converter, a certain amount of current will flow through the resistance and the sustaining coil has to keep the con-

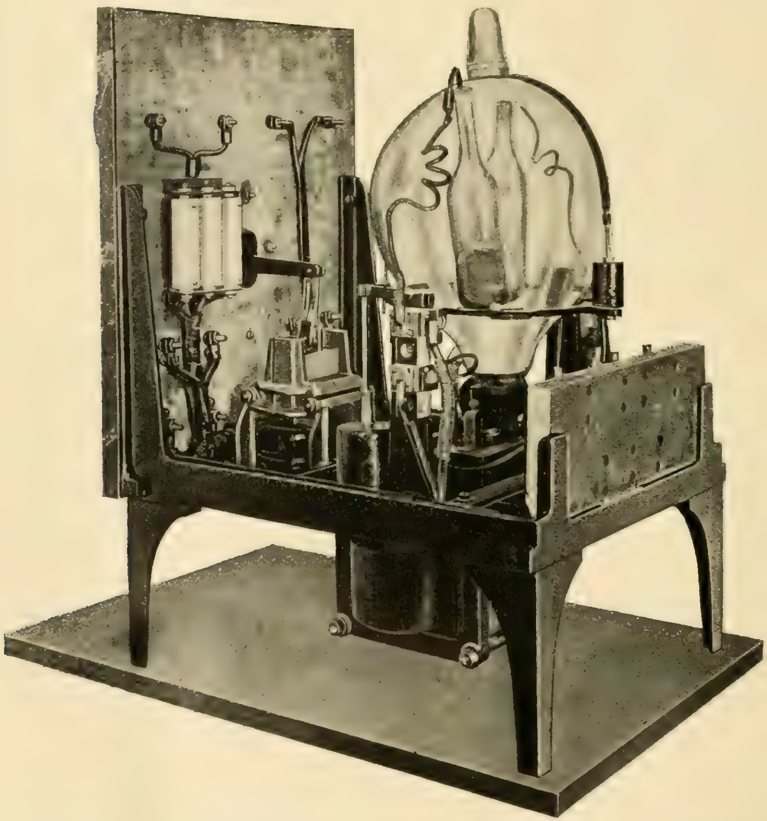
FIG. 8

verter alive only during those periods when the alternating current is below 15 volts. With a battery load, however, the supply can pass current only during those periods when the supply voltage is greater than the battery voltage plus 15 volts, and in case we wish an efficient arrangement the battery voltage must be as near the alternating-current voltage as possible; consequently the sustaining coil has to keep the converter alive during a considerable portion of the cycle.

In case of drop in the supply voltage when the converter is

operating upon a resistance load the result is merely to reduce the current. When operating upon a battery load since the counter e.m.f. of the battery is constant a drop in supply voltage may much more easily cause the converter to go out.

The type PA converter outfit, which is the standard apparatus for charging automobile storage batteries is so adjusted as to stand all ordinary variations of voltage without going out. In case of

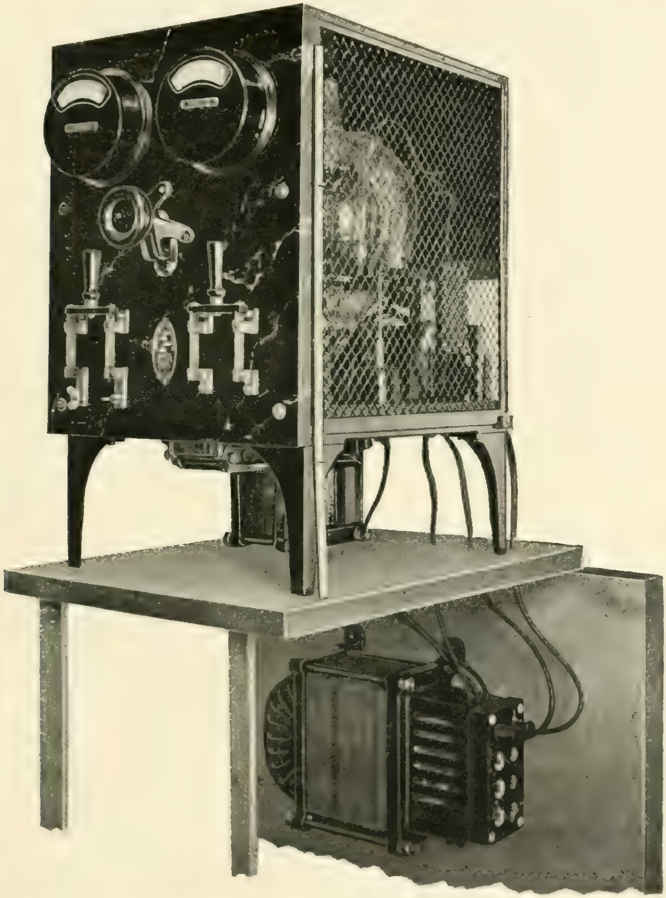


TYPE PA COOPER-HEWITT SINGE-PHASE SELF-STARTING VAPOR CONVERTER FOR CHARGING STORAGE BATTERIES.—REAR VIEW.

Auto-transformer and protecting cage, not shown.

extraordinary drops of voltage the apparatus, being automatic, starts itself again after the return of the supply. This apparatus allows a very close adjustment of current and is generally well adapted to the conditions of commercial service.

Further applications of the vapor converters to other work, both larger in capacity and different in character from battery charging outfits, may be looked forward to in the near future.



TYPE PA COOPER-HEWITT SINGLE-PHASE SELF-STARTING VAPOR CONVERTER FOR CHARGING STORAGE BATTERIES.—FRONT VIEW.

The auto-transformer is shown underneath the shelf. The two-foot rule at the near corner will give an idea of the size.

The ultimate limits of the place in the electrical field to be taken by this apparatus will not be determined for some time to come.

THE SINGLE-PHASE RAILWAY SYSTEM, ITS FIELD AND ITS DEVELOPMENT

CHAS. F. SCOTT

AN interesting discussion upon railway matters took place at the Great Barrington meeting of the American Institute of Electrical Engineers three years ago. In this discussion two things were clearly shown; first, that alternating current is a necessity for heavy and long distance traction and second, that no system was presented which fully met the requirements.

A remarkable change has taken place in railway engineering during the past three years and as many who have not given close attention to the matter may not be familiar with the views of various engineers and the important advances which have been made in the development of the single-phase railway system, it will be worth while to review the status of electric railway engineering just prior to the announcement of the single-phase railway motor and to note the engineering evolution of the system since that time.

At the Institute meeting three years ago several important papers upon railway subjects were presented and various methods of operation were proposed and discussed. Mr. B. J. Arnold presented the Arnold electro-pneumatic system in which "a single-phase or multi-phase motor mounted directly upon the car operates the car through a pneumatic storage system." Mr. Arnold evidently regarded the use of alternating current as the fundamental feature, for he says, "Whether my system proves the correct solution of the question or not, I firmly believe that the alternating-current motor will finally prevail for heavy railway work."

Mr. H. Ward Leonard referred to a locomotive under construction at the Oerlikon Works in which by his system single-phase alternating current is received and transformed by a motor-generator set upon the locomotive into continuous current for supplying motors upon the axles.

Mr. A. H. Armstrong referred to the use of the polyphase system abroad but added, "If alternating-current motors are used, the single-phase is preferable and may or may not be of the ordinary induction type."

Mr. W. B. Potter indicated that the urgency for the use of single-phase current in the supply circuit was so great as even to justify its transformation into polyphase or into direct current on the car provided no suitable single-phase motor was forthcoming.

These various suggestions are all cumbersome methods proposed to secure the use of single-phase alternating current and the justification for them all is summed up in Mr. Potter's statement (June, 1902) "That at present there is no simple and satisfactory [single-phase series] motor or method of operation."

Taken altogether this is a most effective expression by prominent electric railway engineers of the demand for a simple and adequate single-phase system.

At the next meeting of the American Institute of Electrical Engineers in September, 1902, Mr. B. G. Lamme, chief engineer of the Westinghouse Electric & Manufacturing Company, presented a paper describing a single-phase series motor and method of control which had been developed and for which a contract had been taken for a road between Washington, Baltimore and Annapolis. The motor which Mr. Lamme described was of a similar type to that ordinarily employed for operation by direct currents but embodied various features of importance which specially adapted it for operation by alternating currents without impairing its efficiency as a direct-current motor. In running through the discussion upon this paper one is impressed with the surprise manifested as to the form of motor which is employed, with the incredulity expressed as to the possibility that a motor of this type could render satisfactory performance and also with the appreciation of the important advance which had been made provided Mr. Lamme's claims were substantiated.

Some of the leading electrical and railway men took part in the discussion. Mr. C. P. Steinmetz of the General Electric Company said: "I believe we can congratulate ourselves that here is published the record of some work done in the direction of developing apparatus giving the proper characteristics for alternating-current railway work. I must confess, however, that I have been somewhat disappointed in reading this paper, by seeing that after all this new motor is nothing but our old friend the continuous current series motor, adapted to alternating currents by laminating the field." Mr. Steinmetz then refers to the Thomson repulsion motor indicating its suitability for railway work. "Now it was this alternating current single-phase repulsion motor which I was thinking of when in some previous discussions on alternating-current railroading I mentioned the inferiority of the induction motor and stated that alternating-current railroading will become feasible only when the single-phase motor is developed, giving characteris-

istics of the series motor." It is thus seen that Mr. Steinmetz agrees with others in believing that alternating-current railroading is feasible only with the single-phase motor, either the series type or the repulsion type, and he had concluded that the repulsion type was the more promising.

Mr. B. J. Arnold, of the electric traction commission of the New York Central Railroad, in the same discussion said: "I think that the essence of his (Mr. Lamme's) paper is summed up in one paragraph, in which he says that he has succeeded in making an alternating-current, single-phase motor operate in starting under load by means of a commutator, without sparking. If Mr. Lamme accomplishes this successfully he is entitled to great credit and I have no doubt that he has largely accomplished it since he says so, on his experimental motor, but he has not done it yet on the scale he hopes when he gets his railway running, and if he does it efficiently on a large scale with motors of the size he speaks of operating under the varying condition of railway work, he will deserve all the credit we can give him."

The editorial comments of the American technical press which accompanied the publication of the paper were in substantial agreement with the opinions expressed by Mr. Arnold. The views of the London Electrician given on October 31st, 1902, are of interest, as presenting a general review of single-phase railway systems, taking up the repulsion motor, the series motor and the Ward Leonard converter system. "Repulsion motors," it is stated, "have been constructed from 10 to 15 hp.; it remains to be seen whether it is possible to develop this motor on the scale necessary for traction purposes with a good efficiency and power-factor; at the present time it is of no value for traction." Regarding the single-phase series motor presented by Mr. Lamme in his American Institute of Electrical Engineer's paper, the editorial said: "If this motor fulfills in practice the expectations formed from its behavior at Pittsburg, it will give a complete solution of the problem of single-phase railways, and a notable advance will have been made in electric traction."

Professor Osnos in Elektrotechnische Zeitschrift, January 7, 1904, in a general article on the inception and operation of the single-phase commutator motor gives a good perspective view of the circumstances incident to the bringing forward of the single-phase railway motor in the following terms: "The courage required to take a machine which had been a failure and at the time almost universally given up as hopeless, as the series alternating-

current motor was, to undertake experiments on a large scale and to bring the machine to success, is not to be underestimated. * * * To Mr. Lamme belongs therefore the credit of being the first to give the single-phase system wide publicity and to bring general attention to the possibility of a practicable operation with single-phase alternating-current commutation motors."

Since it is not unusual to find many other inventors pressing prior claims when announcement is made of the practical development of a new system, it is surprising in the present case to find no one else claiming to have given serious consideration to the development of the single-phase railway motor. The advantages of the single-phase system as a whole, presented in the paper by Mr. Lamme, coupled with the statement that it was actually possible to secure them, awakened the interest of other engineers with the result that several single-phase motors of various types have since appeared.

Professor Dr. F. Niethammer, in a general article on "Single-phase Commutator Motors," in the Electrical Magazine, London, October, 1904, said: "The most recent period of single-phase commutator motors for traction work was opened by the Westinghouse Electric & Mfg. Company (Lamme) in 1902, referring to the straight series motor. Dr. Finzi followed very soon with results obtained on a street railway series motor of 27 hp. In 1903 Eichberg gave full particulars of the compensated commutator motor of the Union Company, Berlin, and the General Electric Company published data of repulsion motors for traction work."

In America, the General Electric Company, following the suggestion of Mr. Steinmetz above quoted, seems to have taken up the development of the repulsion motor, for in January, 1904, two papers were presented to the American Institute of Electrical Engineers by engineers of that company, one on the single-phase repulsion motor by Mr. Walter I. Slichter and the other on the alternating-current railway motor by Mr. C. P. Steinmetz. These papers lay emphasis on the repulsion motor and indicated that the authors preferred this motor to the series motor. In the discussion which followed these papers, Mr. Lamme said that his original paper described two types of single-phase motors suitable for railway work of which he preferred the series to the repulsion type. He further said that his subsequent work had not changed his views and he gave in detail his reasons why the series motor was superior to the repulsion motor.

In the following August there appeared in the technical journals a description of the equipment of a car with single-phase motors entitled, "Compensated Motor Railway Equipment of the General Electric Company," which indicated that not the repulsion type of motor, but the "compensated series" form was used. The article was accompanied by the following editorial comment in the Electrical World and Engineer: "It is a singular fact that both the Westinghouse and General Electric Companies have adopted the so-called straight series motor of the compensated type, the machine used by the two companies differing more in mechanical details than in electrical characteristics. This has been the cause of no little surprise, for every indication previously had been that the latter company was committed to the development of the repulsion type of motor."

The verdict of American engineers may be safely taken to be that the compensated series type of motor first used by the Westinghouse Company and finally taken up by the General Electric Company is the one best suited for railway work. Various types have been employed by foreign manufacturers but there is apparently a strong leaning toward the type which has been adopted in America.

The activity of electrical engineers and manufacturers all over the world in the development of the single-phase railway system is a matter of the greatest significance in the field of heavy traction, which is probably the most important electrical problem at the present time.

I have been closely associated personally with the development of the single-phase railway system. In the spring of 1901 Mr. Lamme said to me that the results of tests on some recent alternating-current commutating motors satisfied him that it was practicable to design a successful single-phase motor suitable for heavy railway work. This was the beginning of the present single-phase activity. Railway development was reaching the point where such a motor was required. Designs were at once prepared and motors of 100 hp. capacity were built and tests were made the following fall. The motors met expectations and also indicated wherein improvements could be effected. The development work continued. Mr. Lamme's Institute paper, by the way, contains not merely a description of a motor but it treats broadly of the single-phase railway system, taking up the various elements and indicating the reasons for each. The development of the single-phase railway

has followed closely the lines laid down in the original paper. This is certainly in great contrast to the early development of the direct-current motor. One of the striking features of Mr. Sprague's interesting article in the June Century Magazine is the account of the great variety of apparatus proposed during the first eight years of railway development. In 1887, when the total electric railway mileage of the world was less than sixty miles, there was a great variety in the styles of equipment. Motors were placed on the platform and under the middle of the car, as well as on the trucks. The number of kinds of third rail and side rail and overhead trolleys was legion, and voltages ranged from 100 volts up. It is true that the single-phase system does not have to go through the kind of development which was necessary in the early days. On the other hand, it is fortunate that the single-phase apparatus approximates so closely to the direct-current types that past experience is directly applicable. In fact the new elements in the single-phase system are mainly those which overcome the limitations in the direct-current system.

A recent paper before the American Institute of Electrical Engineers contained tables giving characteristics of steam locomotives upon the principal railways of North America. Only one of these eighty-three locomotives, however, is equal either in weight on drivers or in draw-bar pull to the single-phase locomotive exhibited by the Westinghouse company before the International Railway Congress in its recent visit to Pittsburg.

A legitimate conclusion from the foregoing statements is that electrical engineers are, in the main, in substantial agreement:

First. That the use of single-phase alternating current is essential for heavy and long distance railway service.

Second. That a single-phase motor and single-phase system fulfilling the ideal requirements have been developed; and,

Third. That engineers all over the world are substantially agreed that one form of motor, namely the series compensated single-phase motor, is the motor best adapted to meet the demands in heavy railway traction.

EXPERIENCE ON THE ROAD

A SECOND ARTICLE DEALING WITH REAL THINGS ON THE ROAD

H. L. STEPHENSON

IN a large percentage of the cases which an engineer investigates, he is not usually supplied with data from which he can draw any conclusions whatsoever as to the nature of the trouble. Indeed it is quite common not to know beforehand what sort of an installation it is, even whether it be alternating or direct-current. Then when you are on the ground with no other tools than your two hands it takes an infinite amount of patience and a great deal of worry and hard work to finally overcome the trouble. It is this that makes the business such a wonderful developer of the nack of sticking to a thing. In fact the fellows who follow this class of work never know when to give up. It is next to impossible to make them understand when they are beaten.

The charm of this kind of work lies in its novelty. One never knows where the next day will find him. Without a warning he is off on a trip of hundreds of miles to put apparatus in satisfactory service that may be done with a word or to investigate trouble that will baffle the skill of the best engineers. No sooner is one difficulty adjusted and the matter straightened out to the customer's satisfaction than he is lost in another problem that at first appears to be beyond your powers to solve.

A RUNAWAY ENGINE

A recent case of trouble with an engine will serve to illustrate the point. This particular engine was a small, high speed, piston-valve type, direct connected to a 75 kw lighting machine to be driven at 270 r. p. m. When this outfit was started and the engine given full steam pressure, the first speed would probably be 276, and as quickly as another could be taken, 281, then 287, 293, 297, 301, 310, continuing to creep up slowly. With any load from ten kw up, the speed regulation was very good, but whenever the load was thrown off the speed would begin to creep. We ran it throttled until all of its parts had reached an even temperature, but with no better results. The engine-man then took out the valve to look for steam leaks but it seemed to be in good condition and a trial showed that we had not improved it. An improvised device

showed that the governor did its work so that it looked reasonable to believe, despite our indicator cards, that there must be some error in the valve setting. This was checked over, and the piston was taken out and examined. We took cards until there was no more paper to fit the indicator. And so it went for three or four days, until we got hold of the theoretical curve such as engine builders send out as a sort of an advertisement.

In comparing the card with one of our no-load curves the trouble was as apparent as though it had been printed in words across the paper. The valve leaked steam. Taking the valve out for the second time, we peened the inside of the rings to spread them out thereby increasing their pressure against the walls of the steam chest. We had solved the problem, for engines are not made that run better than this one now does.

A LOOSE BRUSH HOLDER

Elevator work is more or less troublesome because these motors are generally installed by outside firms and if anything goes wrong it is usually attributed to a supposed defect in the machine.

A short time ago the writer had to leave some important work to see what could be done with a small direct-current motor in elevator service. On reaching the place he found all hands awaiting his coming and on being informed that the motor seemed to run away and that the brushes threw off sparks like a blast furnace, he was plied with the usual question, "What's the matter?"

The control outfit was of a difficult make and the wires were so concealed that it looked to be a three or four hour puzzle to find out where they went. Before an actual demonstration was made a happy thought prompted an investigation of the brushes, and there they were, just half way between the neutral points so that running the motor in either direction produced a furious sparking.

A SPEEDY ELEVATOR

Another similar case occurred where the man in charge of the installation insisted that the motor was wired according to the diagram and since the elevator ran about four times its proper speed, there was, therefore, undoubtedly, something wrong with the motor. Like the experience just cited there was little difference in the speed whether the car was going up or coming down. A drop across the shunt field revealed the trouble at once; the connections

were such that less than 25 per cent. of the line voltage reached this part of the motor, and when the foreman stated that he did not see how this could make any difference it was necessary to make the changes in the wiring to demonstrate to him that there was nothing wrong with the machine.

EXCESSIVE METER BILLS

A peculiar case with induction motors was one where the customer ordered the machine investigated. There was no complaint as to the machine itself, its service was excellent and there was nothing about it that would indicate that there was any trouble except that his monthly bill for this elevator was just double that of two similar elevators and he did not think there was enough extra service to justify such a difference in his bills. This two-phase motor was run on a two-phase three-wire system where the voltage between the middle and each of the outside wires was 220 volts and between the two outside wires, 310 volts. A voltage reading was taken at the motor at each of the two sets of terminals while the car was in motion which read alike on both phases. Nothing about the working of the mechanical end of this outfit suggested that this motor was doing more work than either of its neighbors, but to make sure of this, it was decided to make a test that would show the power used and the power-factor. To serve as a check, readings were taken on one of the other elevators before we put the instruments in the circuit of the disturbing machine. The results were identical with our previous readings on the one phase, with the car going either up or down, and the same thing was true on the other phase when the car was going up. But on coming down the capacity of the meters was taxed to the utmost to record just what was going on. Such an excessive flow of current could only be accounted for by supposing that this phase of the windings received the voltage between the two outside wires rather than the 220 volts for which the machine was designed. A check reading of the voltage at the motor terminals showed that this was the case but that in our first reading of this same voltage we had overlooked the fact that the device for changing the direction of rotation could make a change in the way the phases were delivered to the motor.

A TRANSFORMER FIRE

A telegraphic request, "Trouble with new transformer, send man at once," took the writer off once on an eighteen-hour trip.

The customer had installed this unit and on putting it into service it gave entire satisfaction but in two or three hours some one noticed smoke pouring from the transformer house in such volumes that it was thought the whole building was on fire. An investigation showed that it was only the new transformer and a careful examination revealed nothing further than that the smoke came from the grease and dirt burning on two of its low tension terminals, which from all appearances had reached a temperature far above 100 degrees centigrade. The attendants were at a loss to account for this as these terminals were joined together by a short copper strap and were therefore necessarily at the same voltage and, of course, there could be no heating on account of a slight leakage of current jumping from one to the other. This transformer was of that type designed to give either 110 or 220 volts on the low tension side, and as it was operated on the latter voltage, this copper strap put the two windings in series. The reader can imagine the chagrin of the attendants when the trouble was remedied by sand papering this strap and the terminals and screwing up the bolts tight enough to make a good contact for carrying the current. As this transformer was run with a load very close to its rated capacity, we afterwards took the precaution to insert an additional jumper.

TRANSFORMERS IN PARALLEL

Often in an installation one is at a loss to conceive how conditions, past or future, could ever have induced an engineer to select the apparatus one finds doing the work. There comes to mind a transformer station designed to furnish power to a factory which in this instance was a considerable part of the day load. The transformers were arranged in four banks of two each, having a capacity of fifty, one hundred, one hundred and fifty, and two hundred and fifty kilowatts respectively; fully justifying the name we gave them—"a litter of transformers." Conditions arose whereby it was deemed best to work them all in parallel and an engineer was dispatched to phase them out and make the changes in the wiring that might be found necessary. It was not long, however, until they observed that one of the smaller banks became excessively hot, more so than the others and it was also noticeable that the larger sizes showed a comparatively small rise in temperature. A test showed that there was considerable difference in the regulation of the different banks, and running them with one

or two sets carrying a load far beyond their rated capacity, would sooner or later result in burning out these transformers. We finally hit on a combination which, by splitting the load, would give the major part of it to the two larger banks.

A RUNAWAY WATER WHEEL

A man on the road is not very often permitted to observe the effect of a runaway engine or water wheel without being responsible, directly or indirectly, for the accident. A case of this kind, however, happened not long since, where a sudden load caused the governor on a water wheel to run the gates wide open and there they stuck. The man at the switchboard lost his head and made no attempt to disconnect the generators from the line. Six miles away we could tell that something unusual was wrong and twice the attendant there tried to disconnect his lighting circuit with a plunger switch which would break a load of forty kilowatts at 2 200 volts, and while he did not have half of this load at the time, the voltage was so high that he was unable to break the arc. The incandescent lamps on that lighting circuit would have put the ordinary arc to shame until they either burned out or exploded. At one residence the family was at dinner and the broken glass from the lamps above the table fell noisily in a perfect shower upon the table. The meters did not have capacity to read what the voltage did reach. Outside of the loss in lights the system was only crippled to the extent of two broken down transformers, though there were fourteen large ones on the line at the time.

A VOLTMETER THAT SOMETIMES WOULD AND SOMETIMES WOULDN'T

There is no part of the training received in the shops that will not be of use to the man outside at one time or another and this I wish to emphasize by citing a case where the writer made a simple but necessary repair which he would never have been able to have made but for a pointer picked up in his first three days in the factory.

It was a direct-current voltmeter of that type where a current passing through a few turns of very fine wire, wrapped on an aluminum movement, sets up a field to act in opposition to a permanent magnet. This instrument would read the voltage one time and the next time it was apt not to register at all. Going over it carefully for loose contacts it became evident that the winding was at times short-circuited on the movement though it appeared

a hopeless task to find where until a sort of an intuition brought the trouble to the surface.

The current in the small winding is carried to the moving element by two springs of equal tension, which work one against the other, holding the pointer on the zero position when the meter is not in service. It is necessary, therefore, when these springs are fastened to the movement, that one be insulated from it which is done by running the spring between a tiny piece of fuller board, where it is clamped to the aluminum arm. The workman in assembling this instrument had gotten the spring outside the paper and since the voltage drop across this winding is very small, it was only occasionally that enough contact would be made to make the meter register.

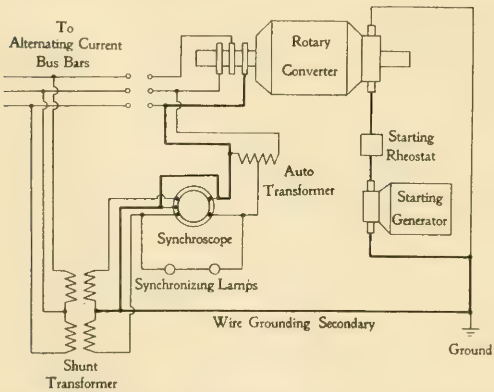
A CASE OF VICIOUS COMMUTATION

It is no uncommon thing to nurse a piece of apparatus through the rush hours and then spend the rest of the day in tearing it to pieces and hustling to get it together for the heavy loads of the morrow. In the large cities where the electric cars must be kept moving and the lights kept burning as long as machinery will deliver power at all, one takes chances that fairly startle one in the calmer moments of reflection.

An instance of this sort once happened when an engineer wandered aimlessly into a station where he had started a small rotary converter for street-car work some ten or twelve days before. He was very much surprised to find that with any load the brushes would spark viciously. Shifting them either way to find a better point of commutation made no improvement. The commutator was in bad shape but even this failed to explain why the machine should behave in this manner when it had so beautifully handled a much heavier load only the week before. A couple of hours finished the day's run and a careful examination revealed the fact that only seven out of the twenty-four brushes were touching the commutator. For some reason the brush tension had been increased to such an extent that the brushes had been ground away until the nuts, which fasten the carbon to the copper shunts, would not let the brush slide farther down in the holder. The cause of the sparking on the heavy loads was clearly due to the lack of sufficient brush area for carrying the current. Since no extra brushes were at hand it took the best part of the night to smooth off the commutator and put the machine in a workable condition.

FIRE WORKS ON PARALLELING ROTARY CONVERTERS

Another converter affair the writer walked into unexpectedly. The attendants were getting the machines started for the morning load and had two of the five 1 000 kw machines in the station already on the line when both suddenly gave a groan and the direct-current breakers came out as though there had been a ground on the trolley. They quickly had one machine on the bus again, but when the second switch was thrown in, the sparks from the brushes on each machine would have done credit to a fourth of July celebration. The machines seemed fairly to stand still until the direct-current breakers performed their duty. They were fortunate in selecting the right one of these two and, getting the rest of the rotary converters on the line with it, they went through the rush hours without crippling the service. What really had happened was that one of the big alternating-current generators at the main station had been thrown on the high tension busses out of phase and in some inexplainable way the polarity of the one rotary converter had been reversed and throwing their direct-current ends together made a short-circuit that was worthy of being patented.



GROUNDING THE SECONDARY OF THIS TRANSFORMER RESULTED IN A SHORT CIRCUIT, AS SHOWN BY THE HEAVY LINE.

GROUNDING THE SECONDARY OF A TRANSFORMER

In the rules of the National Board of Underwriters, it is recommended that some point of the secondary winding of a transformer be grounded and following this out came near making trouble at one sub-station. The installation was the ordinary rotary converter, started as a direct-current motor by a motor-generator set. A synchroscope was used in synchronizing and was connected on the line side to two small transformers while the machine voltage was taken care of by a small auto-transformer of the style for mounting on switchboards. This ground wire had just

been put on when the writer reached the station. He was in time to see the first machine tried, and pour forth a cloud of smoke equal to that from a big freight locomotive. One wire of the synchroscope was all but melted. This new ground completed a path that was virtually a short-circuit on the starting generator. A glance at the heavy line on the sketch will enable the reader quickly to see and appreciate the circumstances.

A TIME HONORED TROUBLE

A paper of this kind would not be complete without mentioning some experience with the series fields of compound machines. Tell a roadman that a motor's speed is not right or that a generator will not hold up its voltage and the first thing that comes to his mind is the series field. This seems a simple thing but any one with road experience can cite a number of cases where trouble was due to wrong connections on this part of the machine. It is not at all uncommon to find machines that have been run so long at an excessive speed to keep up the voltage at full-load, that the proper pulleys have been lost and when the trouble is discovered it takes a month or two before the change can be made and the generator belted properly.

Alternating-current apparatus is not altogether free from this same trouble. A good example comes to mind in the case of a composite wound generator which had been in service for two years but only at the end of that time did it begin to receive any where near its rated load. A complaint was made that this machine would not hold up its voltage with the separately excited field having a drop of 110 volts direct current. As the reported full-load voltage was not excessively low we concluded that a bad power-factor was responsible for some of it and with that end in view an elaborate test was arranged to be taken in the presence of the officials of the power company. The engineer who went to the plant discovered that in all probability during the two years they had been running, the self-excited coils had been bucking against the separately excited winding and reversing this—well, the truth is, we do not care to hurt the feelings of any one by commenting on things of this sort. Reversing this cured the trouble.

ARMATURE WINDINGS OF ALTERNATORS

PART II OPEN-TYPE WINDINGS - Continued

F. D. NEWBURY

TWO-PHASE OPEN-TYPE WINDINGS

If two wires are located on the armature so that when one wire is under the center of a field pole the other is midway between two poles the e. m. f. in the first wire will be a maximum when that in the second wire is zero. The two e.m.f.'s will then differ in phase one-quarter period, or 90 degrees, and these two wires connected to two independent circuits will form a two-phase winding. Such a winding for a number of poles is shown in Fig. 8, there being one wire per pole in each of the two phases. The extension of the two-phase winding from two single wires to the winding of Fig. 8 or to the still more practical winding having a number of slots for each phase per pole, only requires the application of principles previously explained in connection with single-phase windings. The two-phase winding is nothing more than two single-phase windings properly located on the armature. The only new thing is the principle involved in the proper location of the two windings.

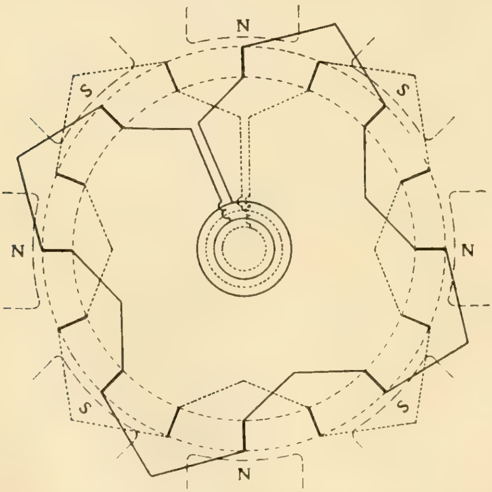


FIG. 8—TWO-PHASE WINDING—ONE SLOT PER POLE PER PHASE

In windings with more than one armature slot per pole in each phase, in order that the e.m.f.'s of the two phases shall be 90 degrees apart the slots under each pole must be equally divided between the two phases and the slots of each phase must be located symmetrically with respect to each other. The slots of each phase need not be consecutively located, although they are usually so arranged, in order to obtain the maximum possible e. m. f. with a given number of conductors.

The relation existing between the location of the armature

conductors and the phase of the e. m. f. in them is so fundamental to polyphase windings that it is worth while to consider this in greater detail. With equally spaced slots the difference in phase between the e.m.f.'s in the wires in consecutive slots will be equal. One pole corresponds to 180 electrical degrees, so with six slots for each pole, as shown in Fig. 9, there will be 30 degrees difference in phase between the e.m.f.'s in the wires in consecutive slots, as shown in Fig. 10. In Fig. 9, *a, b* and *c,* are the slots of one phase, and *d, e* and *f* the slots of the other phase. The resultant e.m.f. of one phase is *O C,* Fig. 11, and the resultant e.m.f. of the other phase is *O F.* The difference in phase is 90 degrees, as it should be, in a two-phase winding. It is evident that the difference in phase will continue to be 90 degrees as long as the slots per pole are equally divided between the two phases and the slots are symmetrically arranged as already pointed out.

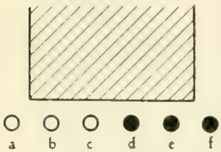


FIG. 9—TWO-PHASE ARRANGEMENT—THREE WIRES PER POLE PER PHASE

To a much greater extent than in single-phase windings, in two-phase windings different mechanical conditions necessitate different forms of coils and connections. One or two coils per slot, open or partially closed slots, an odd or even number of slots per phase per pole, wire-wound coils or single bars; all these, singly and in combination, necessitate different forms of windings. A description of this almost endless variety is beyond the purpose of this article. It will be sufficient to call attention to the more important of the general mechanical features. With one coil per slot two forms of coils, as shown in Figs. 12 and 13, are in common use. The coil of Fig. 12 is comparatively complicated in shape and in order that the different coils shall fit together an accurately made winding mould is required; for these reasons this form of coil is costly to manufacture. On the other hand, for windings having an even number of slots per phase per pole, all of the coils in the winding are interchangeable, so that only one mould is required. On account of its intricate shape the use of this coil is limited to armatures having open slots for which the coils can be wound on a mould in a winding lathe.

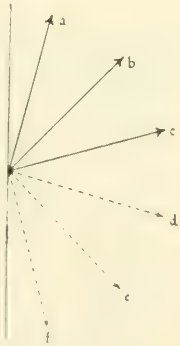


FIG. 10

The coils shown in Fig. 13 are comparatively simple in shape, do not require an accurate mould, but the different coils of the winding are not interchangeable. As many different moulds are required as there are coils in a group. On account of their simple form these coils may be used in armatures having partially closed slots. They are also used in open-slot armatures in many cases.

In two-phase as in single-phase windings the coils of each phase for one pole are divided in two groups, as shown for the single-phase winding, in Fig. 6. The decrease in space required by the end connections and in the number of sizes of coils required is obvious. Where there is an odd number of slots per phase per pole the coils are equally divided, as nearly as possible, between the two groups; for example, with three slots per phase per pole there will be one coil in one group and two coils in the other group.

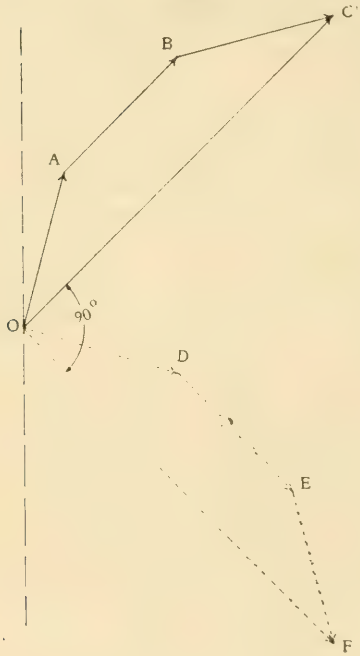


FIG. 11

What has been written concerning the parallel connection of single-phase windings is equally applicable to two-phase windings considering each phase as a single-phase winding.

THREE-PHASE OPEN-TYPE WINDINGS

Just as a two-phase winding may be considered as two single-phase windings, so a three-phase winding may be considered as three single-phase windings properly located on the armature. The connections between the wires composing each of these three circuits are determined by exactly the same principles as if each of the circuits were a separate single-phase winding. The proper relative location of the three circuits is determined by the same principles that govern two-phase windings. The three e. m. f.'s are 120 electrical degrees apart, so that if the winding were composed of three wires they would be located a distance apart equal to one-

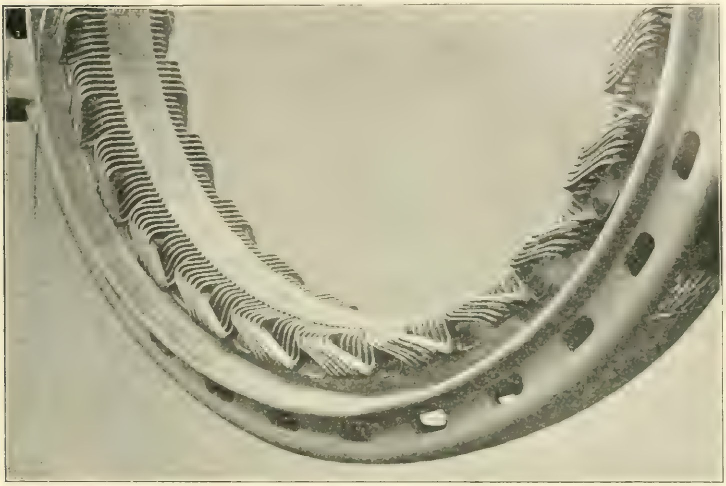


FIG. 12—TWO-PHASE WINDING, COILS IN OPEN SLOTS, THREE SLOTS PER PHASE PER POLE. THE COILS OF EACH PHASE PER POLE ARE IN ONE GROUP

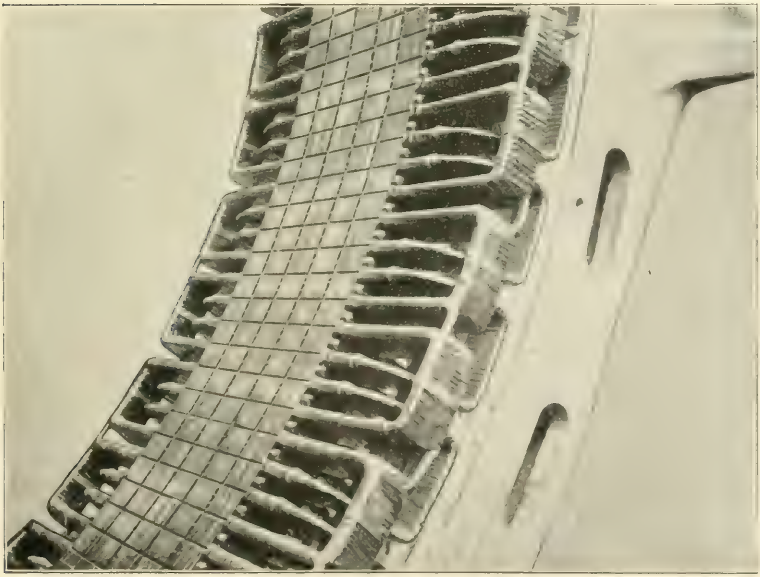


FIG. 13—TWO-PHASE WINDING, ONE COIL PER SLOT, TWO SLOTS PER PHASE PER POLE. THE COILS OF EACH PHASE PER POLE ARE IN TWO GROUPS

third of the spacing of two poles. With more than one slot per pole in each phase the slots per pole are equally divided among the three phases and the slots of the different phases are located symmetrically with respect to each other. That this results in e.m.f.'s 120 degrees apart may be shown in the same way that was employed in considering two-phase windings.

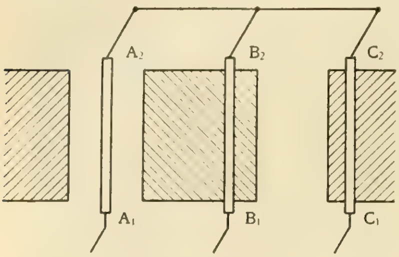


FIG. 14—THE FUNDAMENTAL THREE-PHASE ARRANGEMENT—ONE CONDUCTOR PER PHASE

If the three circuits in a three-phase winding were kept electrically separate in the same way that the two circuits of a two-phase winding are kept separate, nothing more concerning the electrical features of three-phase windings need be written. But three of the six leads from the three circuits are connected together and only three leads are brought out from the winding. This is the so-called *star* or *Y* connection. It is possible to do this because when the three circuits are properly connected together the resultant current at the common point will be zero, which makes a return circuit unnecessary. It is obviously necessary to know which of the six leads should be connected together.

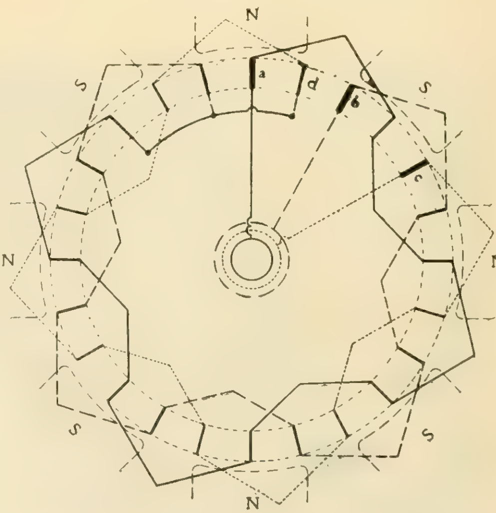


FIG. 15—THREE-PHASE WINDING—ONE SLOT PER POLE PER PHASE

Fig. 14 represents a three-phase winding consisting of three wires, one for each phase. With the wires located as shown, the three e.m.f.'s will be 120 degrees apart, considering the external circuit in the same direction through the three armatures conductors, i. e.,

considering the external circuits in the direction A_1 to A_2 in phase A and B_1 to B_2 in phase B and C_1 to C_2 in phase C. Then A_1, B_1 and C_1 will be three terminals of the winding and A_2, B_2 and C_2 will be the common connection. The extension of the elementary winding of Fig. 14 to the more practical form of Fig. 15 is obvious. In this diagram the three leads of the winding

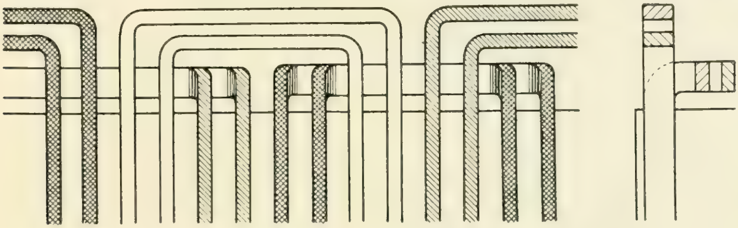


FIG. 16—COILS PER PHASE PER POLE ARRANGED IN ONE GROUP

and the three leads to be connected together are determined in the same way as in the elementary diagram. The three terminals of the winding are similar ends of any three conductors 120 degrees apart. Three such conductors are distinguished in the diagram by heavy lines. The three leads to be connected together are obviously the other ends of the three circuits.

Another method commonly used to determine the leads of the

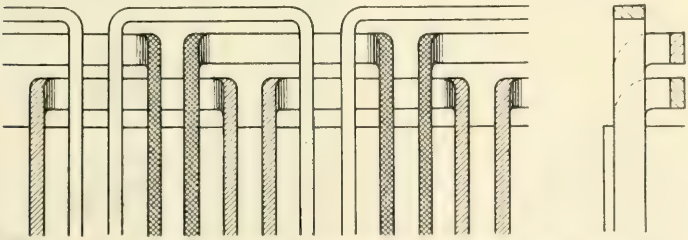
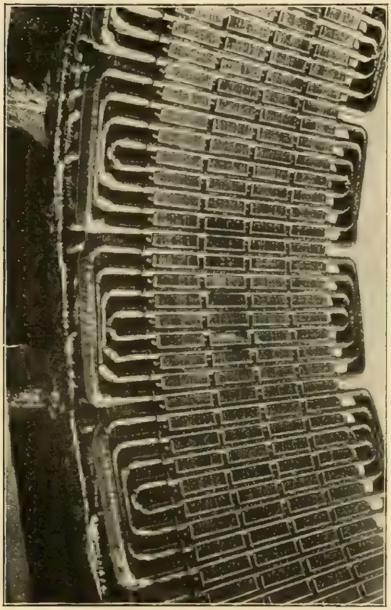


FIG. 17—COILS PER PHASE PER POLE ARRANGED IN TWO GROUPS

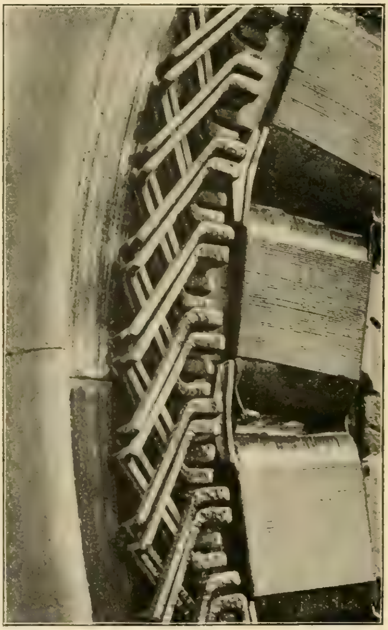
winding is to consider three conductors the e. m. f.'s in which are 60 degrees apart instead of 120 degrees, as in the previous method. Considering these conductors, e. m. f.'s 120 degrees apart will be obtained if the circuit containing the center conductor of the three is reversed relatively to the external circuit. Therefore, of the three similar ends of the conductors chosen the two outside ones will be terminals of the winding, while the middle one will be one of the terminals at the common connection. That this result is the same as that obtained from the first method may be shown by the aid of Fig. 15. In the first method the similar ends of the three

conductors *a, b* and *c,* 120 degrees apart, would be taken as the three terminals of the winding. In the second method the three conductors, *a, d* and *b,* 60 degrees apart, would be considered; the similar ends of the two outside ones, *a* and *b,* would be two terminals of the winding and the corresponding end of the middle one *d* would be one of the leads for the common connection. This checks with the diagram, the terminals in which were determined by the first method.



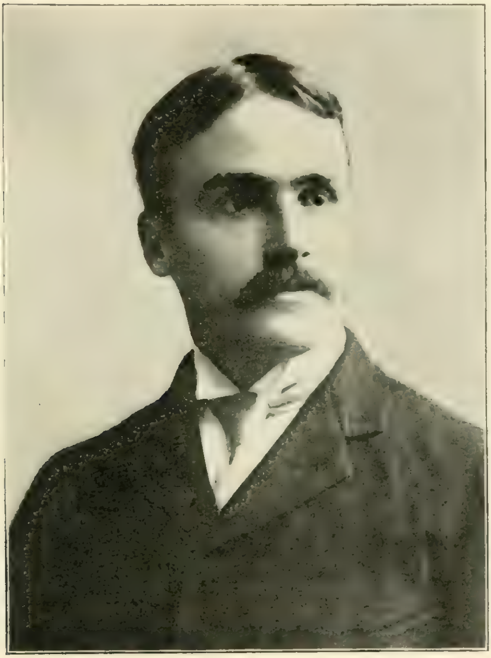
SINGLE-PHASE WINDING WITH UNIFORMLY SPACED SLOTS. EIGHT SLOTS PER POLE, DIVIDED INTO TWO GROUPS

The same forms of coils are used in three-phase open-type windings as in two-phase. In fact, in the majority of cases, two-phase and three-phase windings are invarialy arranged with the coils per pole of one phase divided in two groups, in three-phase windings these coils are arranged in one group. If they were divided in two groups it would be necessary to place the ends of the coils in three different planes, i. e., in three different banks. This is sometimes done when there is a large number of slots per pole per phase, in order to arrange the ends of the coils more compactly. These two arrangements of the ends of the coils are shown in Figs. 16 and 17.



POLYPHASE BAR WINDING WITH SEPARATE END CONNECTORS

MR. WURTS AND THE CARNEGIE TECHNICAL SCHOOLS



ALEXANDER JAY WURTS

Mr. Alexander Jay Wurts has received the first appointment to the faculty of the Carnegie Technical Schools as the head of the Department of Electrical Engineering. Mr. Wurts has received both a general and an engineering education and has been intimately connected with practical electrical development. The selection of an expert and engineer rather than a professional educator as the head of the electrical work indicates the definite practical aims which underlie the Carnegie Technical Schools.

Alexander Jay Wurts was born in Carbondale, Pa., in 1862. He graduated from Yale University in 1883. He then took a post-graduate course at Stevens Institute of Technology, receiving the degree of M. E. This was followed by a special course in electrical engineering under Professor Kohlrausch, of the Polytechnium at Hanover, Germany.

In 1886 Mr. Wurts entered the apprenticeship course of the United States Electric Lighting Company, of Newark, N. J. Some time after he became manager of the Julian Storage Battery Company, of Camden. In 1887 he entered the employ of the Westinghouse Electric Company and became engaged in scientific research and the development of various types of apparatus, which position he held for ten years. During this time he invented the well known

Wurts lightning arrester and devised many appliances of a protective nature.

He was awarded the John Scott Medal by the city of Philadelphia, at the recommendation of the Franklin Institute for the discovery of the non-arcing metals.

In 1898 Mr. Wurts with his associates took up the development of the Nernst Lamp for Mr. Westinghouse. In three years, having carried this work to a state of great advancement, a large factory was established in Pittsburg of which Mr. Wurts was made manager.

Last year he resigned his position with the Nernst Lamp Com-

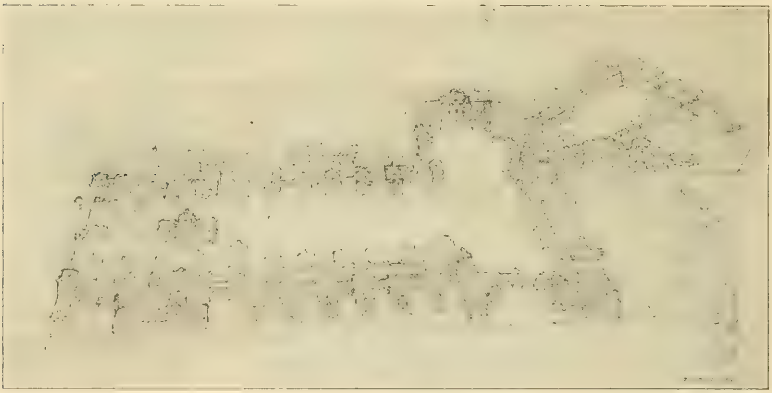


FIG. I—THE COMPLETE PLAN OF THE CARNEGIE TECHNICAL SCHOOLS, COVERING THIRTY-TWO ACRES OF GROUND. AT PRESENT ONLY THE LOWER LEFT-HAND GROUP IS BEING BUILT, AS SHOWN IN FIG. 2

pany, and returned to the Westinghouse Electric & Mfg. Company, where he has been engaged upon some special development work.

About this time Mr. Wurts became connected with the Carnegie Technical Schools on the office staff of the director, and a portion of his time has been spent in preliminary work for the Carnegie schools and the remainder with the Electric company.

The training and associations which have surrounded Mr. Wurts have given him an acquaintance with electrical work, both theoretical and practical, and he has moreover had under his direction many young men. This has afforded him an excellent appreciation of the engineering field and also of the equipment and training which young men should receive in order to take up electrical work efficiently.

The fundamental purpose of the Carnegie Technical Schools is to give its pupils an efficient preparation both in industrial work and applied science. The scope and scale upon which its plans are

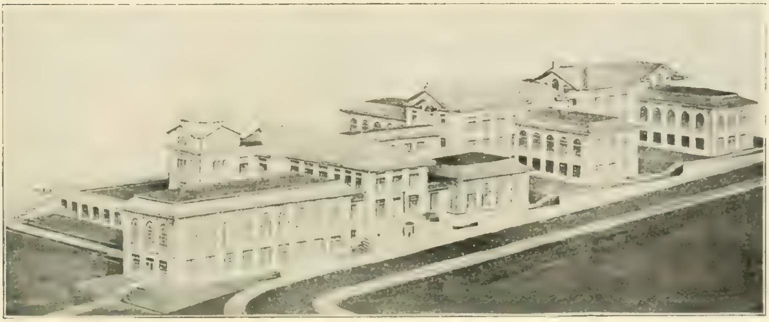


FIG. 2—THE GROUP OF BUILDINGS IN WHICH THE CARNEGIE TECHNICAL SCHOOLS WILL START NEXT OCTOBER. THIS GROUP COMPRISES THE LOWER LEFT-HAND SECTION OF FIG. I, OR ABOUT ONE-TENTH OF THE COMPLETE PLAN

laid make it different from the universities and advanced technical schools, in that students specialize and prepare in the shortest time possible for their chosen vocations.

In the Pittsburg district particularly, it is found desirable to

FIG. 3—THE CARNEGIE TECHNICAL SCHOOLS BUILDING, AS IT IS NOW BEING CONSTRUCTED, IS SHOWN IN THE FOREGROUND. TO THE LEFT IS THE CARNEGIE INSTITUTE, WHICH IS BEING GREATLY ENLARGED

have a technical school which will fit young men, such as those who are leaving the second year in high school, to occupy positions

in engineering fields. Suitable courses will be provided to teach the essentials for various specialties. The school differs from the universities and higher grade technical schools by giving those who have an aptitude or special fitness for the applied sciences, a short definite specialized course. It is further planned that students who have the time and money to take a higher education and study some of its non-essentials, may do so afterwards. Therefore, provision will probably be made by these schools either to teach the non-essentials afterwards or to give its students scholarships in other institutions.

The school is situated in the geographical center of Pittsburg near the Carnegie Institute. The buildings will eventually consist of five groups, viz.: the Administration Building, the School of Applied Sciences, the School of Apprentices and Journeymen, the Technical School for Women and the School of Applied Design. These buildings will not all be built at once, but in harmony with the purpose of the founder, the school is expected to develop from the beginnings which are now made. The Carnegie Technical Schools will start in the large building which is now being erected and will be ready for occupancy in the fall of the current year.

The plans which have been laid out, the field for scientific and technical education in industrial Pittsburg and the ideals and liberality of the donor give promise that this will be a unique and a great institution.

COMPRESSED GAS AS AN INSULATOR*

HARRIS J. RYAN

THE atmospheric gases are the earliest and most familiar forms of dielectric. It was long considered that their resistance to electrical conduction was infinite. Discoveries of comparatively recent years have shown, however, that this property is dependent upon the nature and physical condition of the gas itself.

The first investigations of this phenomenon were made by German scientists who worked almost entirely with gases at various

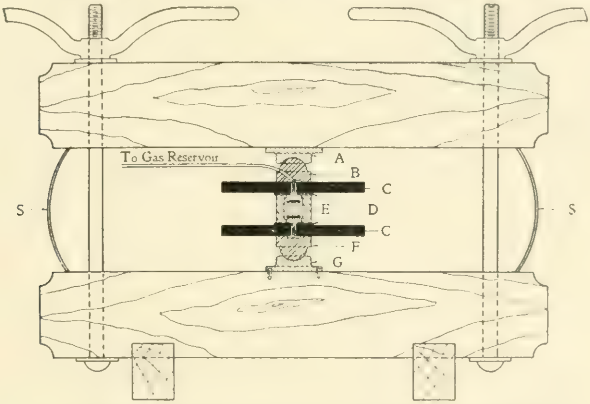


FIG. 1—APPARATUS FOR TESTING THE DIELECTRIC STRENGTH OF GASES UNDER PRESSURE

pressures, at and below atmospheric, using for this purpose various forms of vacuum tubes.

Most noteworthy results were obtained by Paschen who proved that for pressures below and up to atmospheric, the sparking voltage across a given distance in air varies with the gas density, or directly as the pressure and inversely as the temperature. Wolf tested this law up to five atmospheres for oxygen, hydrogen, nitrogen, carbon dioxide and air. His determination of the relative strengths of the above gases will be referred to later.

In 1903, while engaged in studying the laws which govern the formation of corona between the wires of high tension transmission lines, Professor H. J. Ryan discovered a marked discrepancy between his own results and those of others, viz.: the voltage at

*Report of a lecture before The Electric Club by Prof. H. J. Ryan, until recently head of the electrical department of Cornell University, and now head of the electrical department of Leland Stanford University.

This report was prepared by Mr. Robert Rankin, assistant to Prof. Ryan.

which corona loss begins was found to vary even for the same size of conductor and distance of separation. For example, Mershon, working at the Telluride power plant, observed critical voltages which were consistently one-third lower than those obtained at the Cornell laboratory under apparently similar conditions.

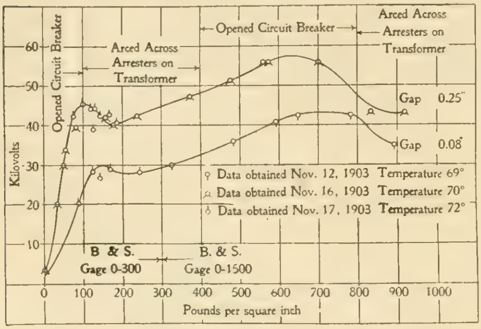


FIG. 2—DIELECTRIC STRENGTH OF GASES UNDER PRESSURE. DATA TAKEN WITH NEEDLE POINTS AND FIXTURE SHOWN IN FIG. 3

The disagreement was proved to be due entirely to the difference in atmospheric density. The voltage to establish the corona in air, other things being equal, was found to be directly proportional to the absolute pressure and inversely proportional to the absolute temperature.†

In order to determine whether the above law would hold for pressures considerably above atmospheric, the apparatus shown in Fig. 1 was designed. This consists of a metal chamber constructed of three parts, *E*, *B* and *F*, the latter two being insulated from the former by three-quarter inch plates of hard rubber, ten inches square. The fixture containing the terminal points is placed in the chamber and supported by brass springs between *B* and *F* as shown. These springs also serve as metallic connection between the electrodes *B* and *F* and the discharge points. A small, high pressure pipe, fitted with a relief cock and a pressure gauge, leads from the cylinder to the gas reservoir. The whole chamber is clamped securely between the beams, the caps *A* and *C* being fitted to the terminals *B* and *F* respectively by a ball and socket arrangement, for flexibility in setting up. The parts marked *D* are two one-tenth inch washers, built up of linseed oil paper and serve to prevent surface dis-

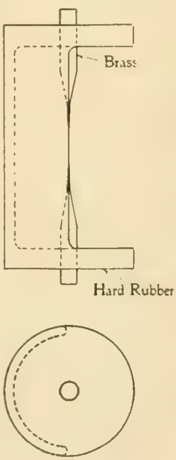


FIG. 3

†Proceedings of the American Institute of Electrical Engineers, February 6, 1904.

charge along the rubber plates from the terminals to the cylinder *E*. As thus constructed, the apparatus will easily hold gas at 1 000 pounds pressure without leakage.

E. A. Eckern, fellow in electrical engineering at Cornell for 1904, carried out the series of experiments to determine the law of gas dielectric strength for high pressures. The work was done largely with needle points which were changed after each discharge.

Fig. 2 shows two characteristic curves thus obtained. It will be noticed that the curves follow practically a straight line law up to about 150 pounds pressure when they become very erratic in form. From this point the voltage required for rupture increases much more slowly than before and in a series of steps. The use of needle points invariably resulted in this form of curve.

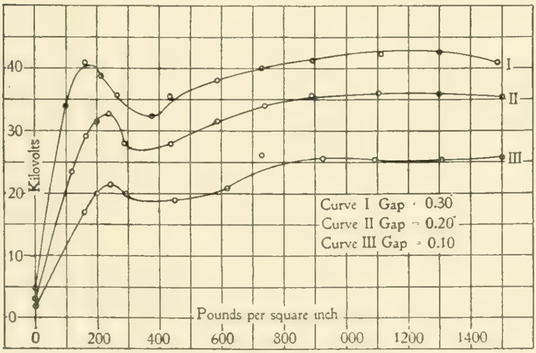


FIG. 4—DIELECTRIC STRENGTH OF GASES UNDER PRESSURE. DATA TAKEN WITH NEEDLE POINTS AND FIXTURE REPRESENTED IN FIG. 5

It was found that the shape and the amount of material in the fixture holding the needle points materially affected the results. The fixture used in taking the curves of Fig. 2 is shown in Fig. 3. Fig. 4 shows a similar set of curves taken with the same kind of needle points, but when using the fixture shown in Fig. 5. Eckern attributed the increased potential for the same sparking distance in the former case to the greater amount of permeable flux carrying the dielectric surrounding the needle points.

To make this point clear, let us assume two metallic terminals surrounded only by a gas dielectric as shown in Fig. 6. If a difference of potential be established between the terminals, electrostatic flux will be set up from *A* to *B*, in just sufficient amount to relieve or hold back the potential. If this potential be gradually increased, the flux will also increase till at some point a certain critical density occurs, when the gas ruptures. Owing to the comparatively dense layer of gas which clings to the surfaces of the

electrodes, the rupturing point usually is not at the surface but at a point just outside of this dense layer.

Evidently, if we place in the neighborhood of the terminals a substance which offers less reluctance to the establishment of electro-static flux than does the gas, we shall have, at any given potential, more flux passing through the less resisting path and less through the gas itself. Therefore we shall have less flux density at any point in the gas for a given potential, and, consequently, it will require a greater potential in the latter case to establish the critical flux value and to rupture the gas. Fig. 7 shows the above case in diagram.

Throughout this discussion, it is assumed that the dielectric flux, constant for a given material, does not vary with conditions imposed upon the gas.

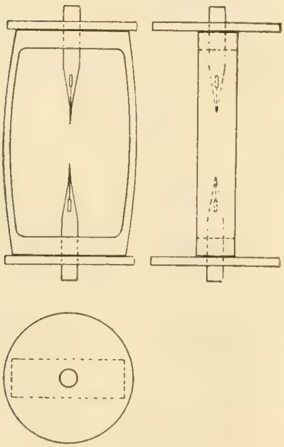


FIG. 5

It must not be forgotten, however, in making use of the principle of Fig. 7 for insulation design, that if the surrounding highly permeable substance be improperly designed, a maximum flux density may be established from it to the electrodes by a path in the gas. This may even cause rupture at a lower potential than would be the case if the more permeable substance were not present. Fig. 8 illustrates this principle. It will be noticed that the permeable substance is so shaped as to cause the flux entering it from the electrodes to converge and thus reach a local high flux density at the point indicated.

Eckern's results may be summed up briefly as follows:—

1. That up to pressures of ten to twelve atmospheres the dielectric strength of air varies directly as the density, i. e., directly as the volume and absolute pressure and inversely as the absolute temperature.

2. That the rupturing voltage for any given density and distance between terminals, is distinctly affected by the proximity of electrostatic flux carrying bodies.

3. That the material of which the terminals are made has little or no effect upon the rupturing voltage for given conditions.

4. That at atmospheric pressure, the rupturing voltage does

not vary directly with the distance between terminals, being proportionally higher for shorter distances.

5. That the properties of air and CO_2 are alike in the above respects.

The results derived by Wolf, as shown later, give a slight difference between air and CO_2. From these and other determinations, it seems probable that item five is only approximately correct.

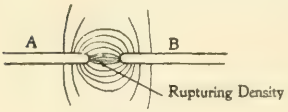


FIG. 6

In continuing the investigations, the past year, the use of needle points was abandoned and rounded aluminum points of about 0.1 inch diameter were used. Fig. 9 shows these points in the fixture. The fixture consists of two hard rubber disks separated by glass rods as shown. The aluminum points were placed at a constant distance apart of 0.1 inch. It was found that such a fixture stands up very well under the high voltages, while the aluminum points are but slightly affected by the discharge and give consistent results when used for several curves. One of these is shown in Fig. 10. The method of taking it was briefly, as follows:

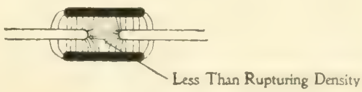


FIG. 7

IMPROVED METHOD OF TEST

In the low pressure side of the high tension transformer was placed a regulating auto-transformer by means of which the voltage could be rapidly and uniformly raised to the desired value. A circuit breaker was connected in series with this circuit, and a voltmeter with a suitable multiplier was placed across the low tension leads. The high tension leads were connected direct to the fixture terminals. Readings were taken on the primary voltmeter at the rupturing value for various gas pressures. This rupturing point was invariably noted by the opening of the circuit breaker.

Having obtained a sufficient number of points, the high tension wires were transferred to a spark gap and a curve determined between the primary voltmeter readings and the corresponding high tension voltages using for this purpose the curve of Steinmetz for needle points. Since both spark gap and gas rupturing voltage are dependent upon the maximum value of the e.m.f. wave, it was possible to plot the curve shown in Fig. 10 directly

FIG. 8

from these readings and those of break-down primary voltage.

In order to ascertain whether a given primary voltage produced a different result with the apparatus connected in, than that which was obtained with the spark gap, the two were connected in parallel, with the high tension leads. At a given gas pressure the break-down point occurred with the same reading on the primary voltmeter and the spark gap as before.

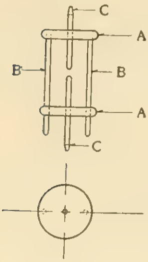


FIG. 9

It will be noticed that the points obtained are for effective sine wave values, instead of the maximum values which actually determine rupture. This is due to the fact that the scale on the spark gap used has its maximum values, as taken from Steinmetz's curve, all reduced to effective sine wave values by dividing by the square root of two. The curve of rupturing volts is, therefore, the true characteristic and is merely the lower curve with its ordinates multiplied by the square root of two.

The above experiments, performed with apparatus of such limited size, are only of qualitative value. That is, they teach only that a comparatively easily attained pressure applied to a gas dielectric will increase its insulating qualities to a remarkable degree. In order that this fact may be made commercially useful, we must look for experiments specifically adapted to the individual cases.

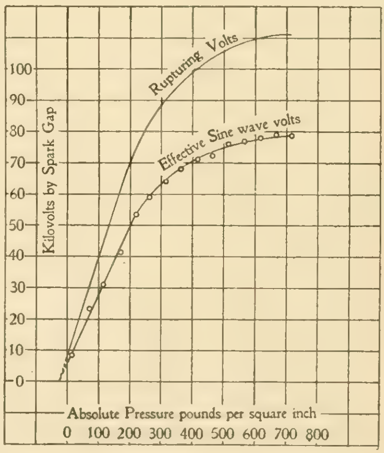


FIG. 10—DIELECTRIC STRENGTH OF CO_2 UNPER DIFFERENT PRSSURES: Diameter of points....0.09375 in. Length of gap........0.096 in. Temperature ....517° A.B.S.

It is interesting to note that the first suggested use of compressed gas was that for which oil was first used, namely, for the insulation of underground cables. Patents fully covering this principle were taken out long before the laws governing it were understood.

Experiments are at present being carried on to determine the advantages of compressed gas as transformer insulation. The well known disadvantages of oil and the increasing voltages called for in all

electrical construction make the facts cited here particularly pertinent as regards this phase of manufacture. Among these disadvantages may be mentioned: the difficulty of shipping and of keeping free from moisture, the danger of the formation of electrolytes such as sulphuric or of free carbon deposits, and danger from explosions. On account of this latter fact, the cases of transformers are at present often built to stand a pressure of 150 to 200 pounds per square inch and it will be noticed from inspection of the curves that in this neighborhood of pressures the greatest benefits are to be derived from gas insulation.

In this connection it may be interesting to compare the insulating strengths of various gases as determined by Wolf, who expressed these strengths in per cent. of the voltage required to rupture air under like conditions. His table from one to five atmospheres is shown below.

Pressure in	Relative Insulating Strength				
Atmospheres.	Hydrogen.	Oxygen.	Nitrogen.	Air.	Co_2
1	.87	.95	1.16	1 00	1.20
2	.76	.93	1.15	1 00	1.10
3	.72	.92	1 15	1.00	1 05
4	.69	.92	1.14	1.00	1.03
5	.68	.9.	1.14	1.00	1.02

We see that there is but slight choice between carbon dioxide and air in the matter of insulation strength and the use of the other gases is evidently prohibitive.

In using gas as an insulator for transformers it is obvious that difficulties will be encountered in bringing leads from the case and in keeping the case tight, while the cooling facilities will be poorer. Further, the gas in no way tends to smother an arc once formed as oil does. This has been proved experimentally. In the use of air there is also a danger from possible explosions which the use of an inert gas like CO_2 will avert. The explosions, in air at a pressure of 200 pounds, of volatile matter which might be distilled from the necessary solid insulation of the transformer winding, is a feature well worth examination. This was forcibly brought to mind during some of the foregoing experiments. A test was being made with the gas at about 300 pounds pressure when an explosion took place of sufficient violence to burst the tube of a 1 500 pound gauge in use at the time. The total amount of gas involved was less than 2.5 cubic inches.

It is probable that compressed gas will not prove a formidable

rival of oil in the construction of the ordinary transformer and that any field it may have will be limited to those cases where the essential requirement is enormous insulating strength, for the sake of which, it may be found profitable to overcome the accompanying obstacles.

HOW TO START ROTARY CONVERTERS*

ARTHUR WAGNER

THE accompanying diagrams show the connections for different methods employed in starting rotary converters, together with the various conditions under which they operate. Standard meter connections and the high-tension circuit breakers are also shown.

Case I.

One three-phase rotary converter operating from alternating to two-wire direct current. The machine is started by a separate starting motor and a synchronizing rheostat.

1. Open all the circuit breakers and switches; cut in all the resistance of the field rheostat.

2. Close the high tension circuit breakers. This energizes the circuits down to switches (1) and (2).

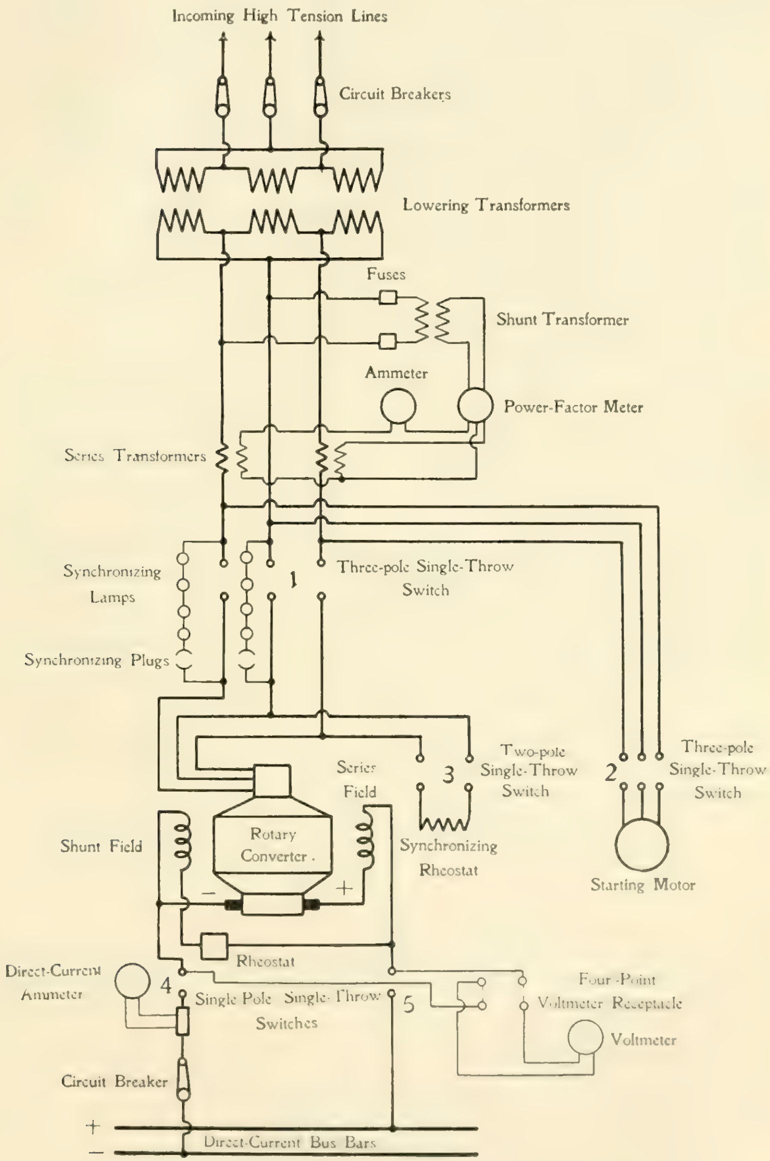
3. Put in the synchronizing plugs, which should cause the synchronizing lamps to burn dimly; put the direct-current voltmeter plug in its receptacle, so that the voltmeter will indicate the direct-current voltage as the converter comes up to speed; bring the alternating current switch (1) within about one inch of closing so that it may be thrown in quickly at the proper time.

4. Close the starting motor switch (2), and before the converter gets up to speed close the synchronizing rheostat switch (3) in order that the rotary converter will approach synchronism gradually. It would be an unnecessary load on the starting motor to start with the synchronizing rheostat in.

5. Adjust the field rheostat to build up the direct-current voltage to approximately the bus voltage. See that the direct-current voltage has built up in the right direction.

6. As the converter approaches synchronism the pulsations of the lamps grow slower; wait until they are slow and regular and then as the lamps are approaching darkness close the alternating-current switch (1). It is better that the switch be closed

*Mr. Wagner's series consists of eight cases each accompanied by a full page diagram of connections.



CASE I.

CONNECTIONS FOR SYNCHRONIZING ONE THREE-PHASE ROTARY CONVERTER, OPERATING ALTERNATING TO TWO-WIRE DIRECT CURRENT. THE MACHINE IS STARTED WITH A SEPARATE STARTING MOTOR AND A SYNCHRONIZING RHEOSTAT.

just before the lamps become dark rather than later, when the converter is receding from synchronism.

7. Open the synchronizing rheostat switch and the starting motor switch and remove the synchronizing plugs.

8. Adjust the field rheostat until the power-factor meter indicates a maximum power-factor, when the alternating-current ammeters will indicate the minimum current.

9. Close the direct-current circuit breaker and the negative and positive switches (4) and (5), thus connecting the converter to the direct-current bus-bars.

THE SYNCHRONIZING RHEOSTAT—The starting motor, which is generally a squirrel cage or short-circuited secondary type induction motor, is designed to run the converter a little above synchronism. The purpose of the synchronizing rheostat is to lower the speed of the starting motor to a point where synchronizing is possible. It is composed of a laminated iron core wound with a copper winding. When connected to the alternating-current side of the converter through the switch (3), as shown in the diagram, it imposes a load on the converter and thus decreases the speed of the starting motor by increasing the slip. Several taps brought out from the winding of the synchronizing rheostat, make it possible to adjust the load and thus secure the proper speed for any particular converter. From time to time as the friction of the set changes it may be found that the speed which the motor gives is not suitable for synchronizing the converter and the speed of the latter can be raised or lowered by cutting in or out on the synchronizing rheostat by means of the taps.

CASE II.

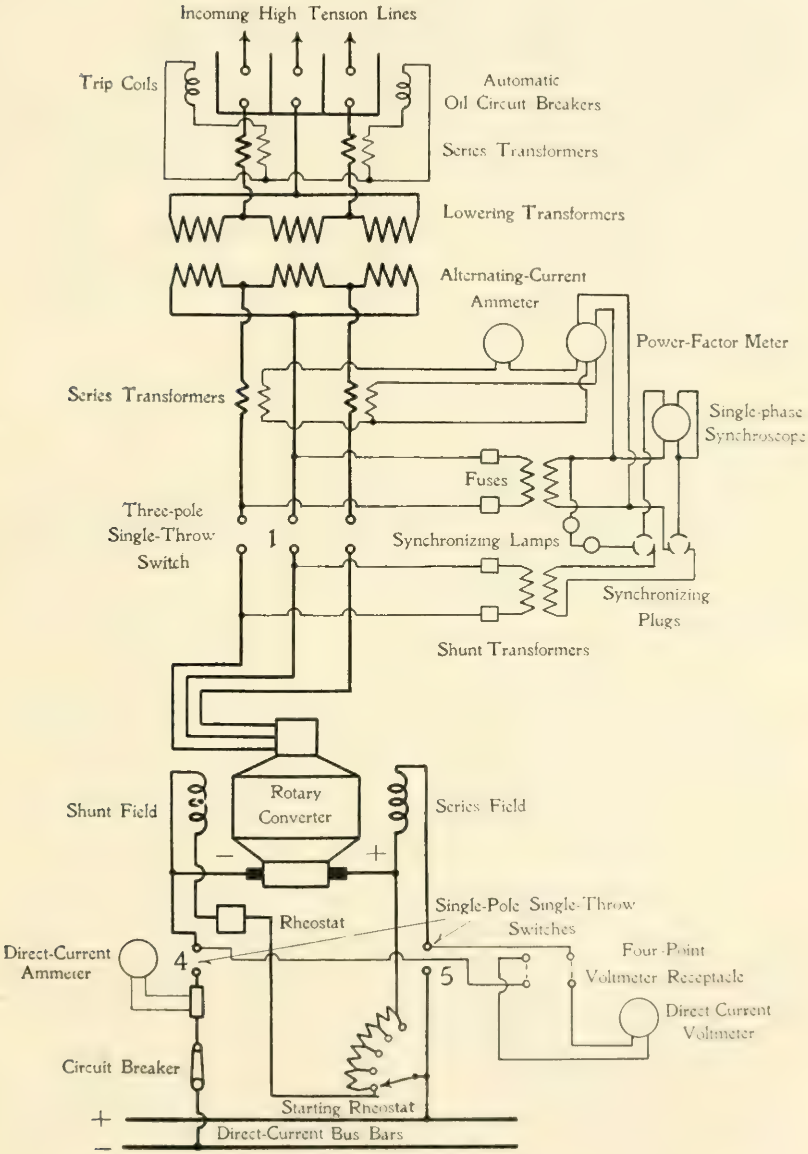
One three-phase rotary converter operating from alternating to two-wire direct-current. The machine is started from the direct-current side as a shunt motor.

*1. Open all the circuit breakers and switches; cut out all the resistance in the field rheostat, in order that the converter will have a strong field for starting as a motor.

2. Close the high tension circuit breakers.

3. Put in the synchronizing plugs, which should cause the synchronizing lamps to burn dimly; bring the alternating-current switches within about an inch of closing.

*Operation 1, Case II. is the same as in Case I.



CASE II.

CONNECTIONS FOR SYNCHRONIZING ONE THREE-PHASE ROTARY CONVERTER, OPERATING ALTERNATING TO TWO-WIRE DIRECT CURRENT. THE MACHINE IS STARTED FROM THE DIRECT-CURRENT SIDE AS A SHUNT MOTOR.

4. Close the direct-current circuit breaker and the negative switch (4), connecting one side of the converter to the bus.

5. Start the rotary converter by gradually cutting out the resistance of the starting rheostat.

6. Regulate the speed of the rotary converter by means of the field rheostat, as in the case of a shunt motor. If the synchronizing lamps do not become entirely dark with each pulsation, the alternating-current voltage of the converter is not equal to the voltage of the line or the secondary side of the lowering transformers, and the direct-current brushes should be shifted slightly. When the synchroscope points vertically upward (simultaneously with the lamps becoming dark) close the alternating-current switches.

7. Close the positive switch (5), short-circuiting the starting rheostat.

8. Cut out the starting rheostat.

†9. Adjust the field rheostat until the power-factor meter indicates a maximum power-factor, when the alternating-current ammeter will indicate a minimum current.

10. Cut out the synchronizing connections by opening the plug switches.

Case III.*

One two-phase rotary converter operating from alternating to two-wire direct current. The machine is started with a separate starting motor and a synchronizing rheostat.

1. Open all the circuit breakers and switches; cut in all the resistance of the field rheostat.

2. Close the high tension circuit breakers.

3. Put in the synchronizing plugs, which should cause the synchronizing lamps to burn dimly; put the direct-current voltmeter plug in its receptacle; bring the alternating-current switch (1) within about one inch of closing so that it may be thrown in quickly at the proper time.

4. Close the starting motor switch (2), and before the converter gets up to speed close the synchronizing rheostat switch (3) in order that the rotary converter will approach synchronism gradually. It would be an unnecessary load on the starting motor to start with the synchronizing rheostat in.

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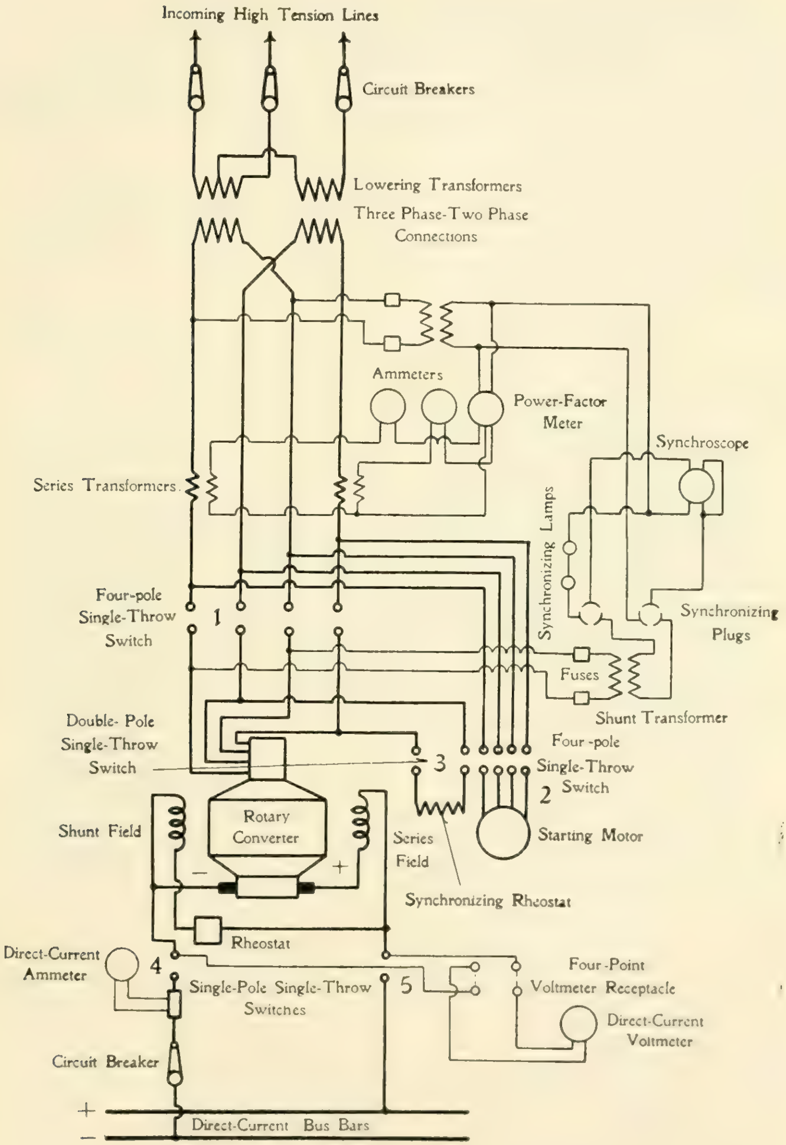
†Operation 9, Case II., is the same as operation 8, Case I.
*Case III. is practically the same throughout as Case I.



CASE III.

Connections for synchronizing one two-phase rotary converter, operating alternating to two-wire direct current. The machine is started with a separate starting motor and a synchronizing rheostat.

5. Adjust the field rheostat to build up the direct-current voltage to approximately the bus voltage.

6. As the converter approaches synchronism, the pulsations of the lamps grow slower; wait until they are slow and regular and then, as the lamps are approaching darkness, close the alternating-current switch (1).

7. Open the starting motor switch (2) and the synchronizing rheostat switch (3) and remove the synchronizing plugs.

8. Adjust the field rheostat until the power-factor meter indicates a maximum power-factor, when the alternating-current ammeters will indicate the minimum current.

9. Close the direct-current circuit breaker and the negative and positive switches (4) and (5), thus connecting the converter to the bus.

(TO BE CONTINUED)

HIGH TENSION TRANSMISSION*

SOME INCIDENTS IN THE DEVELOPMENT OF THE PUYALLUP WATER POWER

J. F. VAUGHAN

Engineer with Stone & Webster, Boston

THE Puyallup river is now generating 20 000 hp for transmission to Seattle and Tacoma, Washington, at a distance of 50 and 30 miles, respectively. The transmission voltage is 55 000.

In the development of the system from its very beginning, there are many interesting details. To begin with the flume, the peculiar features are the smoothness of the curves and the precautions taken to pass off the finer glacial and river sand which, if allowed to reach the water wheels, cuts the nozzles and buckets like a sand blast. Several devices are used to remove the sand, as for instance, deep pockets built into the bottom of the flume at intervals and provided with baffles to prevent churning and blow-offs to discharge the sand; herring-bone shaped plates or knife edges called under-currents, are placed on the bottom of the flume, the apices pointing down-stream. Discharge holes are provided in the flume bottom at the apices. To provide for repairs, the flume is divided into sections by needle gates and spillways at vari-

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*Case III. is practically the same throughout as Case 1.

*Extracts from an illustrated lecture before The Electric Club, April 27, 1905.

ous points, and to regulate the height of the reservoir a large spill-way is located at the entrance to pass off surplus water.

The transmission line is constructed in duplicate throughout. There are two complete and independent pole lines from the power house to Seattle and Tacoma. At Bluffs, junction pole switches are erected by which the two transmission lines may be cut through independently, one to Seattle and one to Tacoma, or both lines put in multiple, or any section isolated without interfering with the operation of the other sections. The wires are of 19-strand, cable (equivalent to 0000 B. & S. gauge) semi-hard drawn, bare copper arranged on a 72 inch equilateral triangle, one three-phase line per pole line.

The transmission line is necessarily the most exposed and the

ONE SECTION OF THE FLUME EMPTYING BROADSIDE INTO ANOTHER SECTION. THE SHALLOW WATER RUNS OVER A SPILL-WAY AND THE SAND AND DIRT SETTLE IN THE UPPER SECTION OF THE FLUME.

weakest part of the system and the insulation is the weakest part of the line. Hence every effort was made to produce a rigid construction and a reliable insulator.

There has been considerable trouble on the coast from the burning and digesting of wooden pins exposed to salt fog. For this reason one of the lines was fitted with galvanized malleable iron pins throughout. As there was then some doubt of the success of this material, the other was provided with eucalyptus pins water-proofed by boiling in linseed oil. The long span construction using steel windmill towers was considered, but abandoned, partly be-

cause it was new and untried, and partly on account of the excellent timber available on the ground for the ordinary construction. More recent experience has brought out the advantages of this construction, and appears to show for a similar work, little difference in cost.

Experience with the iron and wooden pins indicates that the cracking of an insulator throughout means, in dry weather, practically a short-circuit on the iron pin and little trouble on the wooden pin. In wet weather, of course, there is little difference. The greater strength of the iron pin, however, gives it preference over the wooden pin.

With the aid of a log swung in the current of the river from a cable at the headworks, it has been found possible to keep the channel free and in its proper position.

While there was some trouble from the cutting of nozzles and wheel buckets from sand brought down when the system was first started, the sand removing devices appear to be giving fairly good results to-day.

Although insulators damaged by shooting, forest fires, and otherwise, have been badly broken, the lines have shown no indication of weakness. In one case the top of an insulator was wholly destroyed but the operation of the line was not interfered with. Reports to date indicate no failure of insulators due to electrical weakness or other inherent defects.

The telephone line from the power house is carried on cross-arms on one of the transmission pole lines and is connected to the telephone system of the interurban railway and through an oil-insulated repeating coil to the local telephone service in Seattle; which means that part of the line is operated under a 55 000 volt transmission line and part under a 30 000 volt transmission line for a time fed from a different source of power. There is in general less disturbance in these telephones even when talking with the Seattle service than is often found on the lines of the local service itself. Tests for electrostatic induction from the transmission line indicate a difference of potential between the telephone wires and ground of not over 150 volts.

RAILWAY BRAKING

Concluded

PART VIII

E. H. DEWSON

AUTOMATIC PRESSURE GOVERNORS

FOR air brake service an important adjunct to the compressor equipment is an efficient automatic governor to start the compressor when the pressure in the main reservoir has been reduced to a predetermined minimum; and to stop it when the pressure has attained the desired maximum. Many different devices have been manufactured for this purpose and several of the forms most largely in use will be described. The simplest form of governor is illustrated in Fig. 27. It consists of an air cylinder 2 and a piston with its outward movement opposed by a coil spring and the action of an iron-clad electromagnet 16 which surrounds a part of the piston rod. The yoke 10 on the piston rod forms the movable seat of the pressure regulating spring and also the armature of the electromagnet. On the yoke and insulated from it is mounted a circuit closer; when the pressure on the air piston is less than the force of the spring this circuit closer connects two terminals, located on either side of the magnet. The coil of low resistance in the magnet is connected between one of the above mentioned terminals and the motor. The other terminal is connected to the trolley circuit, consequently when the spring has closed the circuit the flow of current energizes the magnet, and its power acting with that of the spring, a greater pressure will be required to open the circuit than that which permitted the springs to close it. This gives the necessary differential between cutting-in and cutting-out pressures. When the switch opens, the magnet loses its power, and as the force opposing

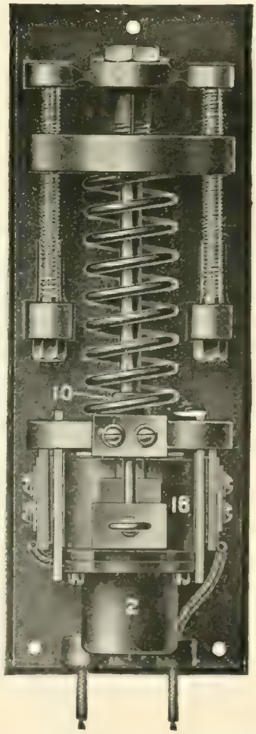

FIG. 27—PISTON MAGNETIC TYPE OF GOVERNOR

the air pressure is thereby suddenly weakened the movement is very quick. The magnet also has a blow-out effect on the two arcs. With this governor the range is practically fixed, but either the maximum or the minimum pressure may be adjusted as desired.

One important street railway system is entirely equipped with this type of governor having over one thousand of them in use.

Another type widely used in straight air service is shown in Fig. 28. It consists of a special switch in the motor circuit, operated by a plunger which is controlled by two solenoid magnets operating in opposite directions. These magnets are controlled by a Bourdon pressure gauge mechanism having a special hand which operates between two adjustable studs or contacts. When this hand touches the minimum pressure contact, current passes through one solenoid which causes the plunger to close the switch. Upon touching the maximum pressure contact the other solenoid is energized and the

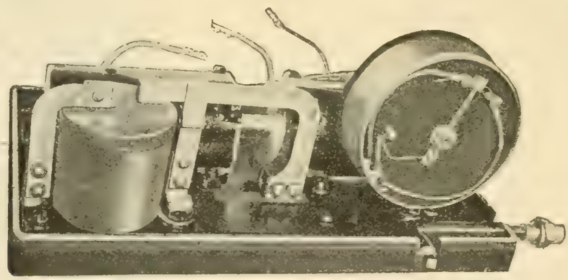

FIG. 28—GOVERNOR WITH SWITCH OPERATED BY SOLENOIDS AND A BOURDON PRESSURE GAGE

plunger opens the switch. Current passes through the solenoids only at the moment of operation as closing the switch short circuits the closing solenoid, and opening it opens the circuit of the opening solenoid. Thus there is no opening of a circuit at the adjustable contacts, and the arcing upon closing these high resistance circuits is so slight that the contacts are very durable. A magnetic blow-out is placed beneath the main switch contacts. Neither of these two governors has any valves and the moving parts are very simple. Such trouble as occurs with them is at the contacts and in the occasional burning out of a high resistance coil.

The governor illustrated in Figs. 29 and 30 is largely used with automatic brake equipments and on interurban lines. The air pressure operates on a diaphragm and is opposed by an adjustable spring. An outward movement of the diaphragm causes the slide

valve to admit air to the lower cylinder where it forces the piston outwardly. This opens the switch, Fig. 30, with a quick rotative movement obtained by means of the quick-break spring, Fig. 29, be-

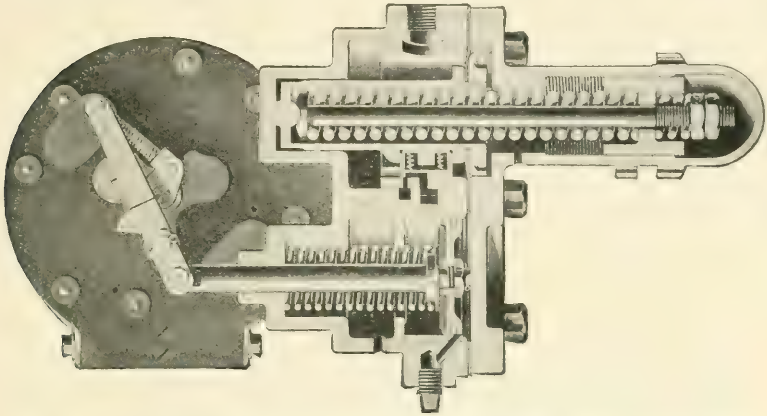

FIG. 29—DIAPHRAGM SLIDE VALVE TYPE OF GOVERNOR—PNEUMATIC PARTS

tween the end of the switch lever and the crank on the switch shaft. An inward movement of the diaphragm due to a reduction of pressure causes the slide valve to exhaust the air from the operating

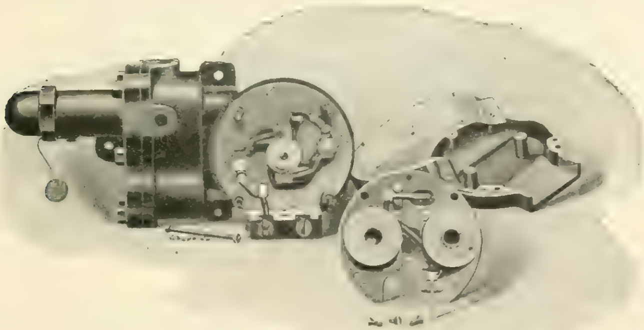

FIG. 30—DIAPHRAGM SLIDE VALVE TYPE OF GOVERNOR—ELECTRICAL PARTS

cylinder, thereby permitting the spring in this cylinder to close the switch. The range between minimum and maximum pressures may be increased by increasing the tension on the retarding spring which opposes the main pressure spring and delays the moving of the slide valve to its release position, as shown in Fig. 29.

When a number of motor cars are operated in a train the

compressors may be made to operate in unison by running a wire through the train connecting all of the compressor circuits together at a point between the individual governors and their motors, as shown in Fig. 31. Thus the closing of one or more of the governor switches energizes this balancing wire and all of the compressors draw from it and continue to do so until the last governor has opened its switch. The snap switch *M* is provided for the purpose of cutting out a disabled motor, the governor remaining in circuit. By means of the switch *R* a disabled governor may be cut out, the compressor on this car then necessarily taking the current from the balance wire. The disadvantage of this system is that the governor which is set the highest of all on the train has to carry the load of all the pumps, which may overload its contacts and blow-out coil, and on long trains a heavy current would be carried by the balance wire.

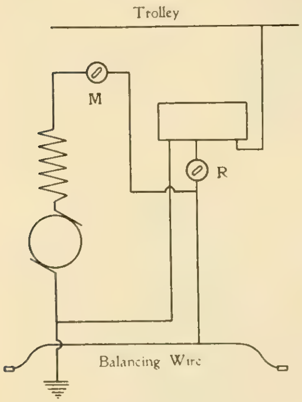

FIG. 31—CONNECTIONS OF A SIMPLE GOVERNOR IN MULTIPLE UNIT SERVICE

A governor which eliminates the overloading of contacts and blow-out coils is shown in Fig. 32. In this governor the switch which controls the compressor on its car is closed by means of a pair of magnets with high resistance coils, and is opened by gravity. The switch magnets are operated by a relay circuit which is controlled by a Bourdon tube contact device like that employed in the plain governor described above. The switches of the relay circuits of all the governors on a train are connected in parallel by means of a balance wire, consequently the energizing of this wire by any one of the Bourdon contactors causes all the individual motor circuit switches to close, providing a simultaneous starting of all the compressors. Furthermore, all of these switches will remain closed until the last relay circuit is opened, i. e., until the governor which is set the highest cuts out, when all the compressors will stop. Fig. 33 shows the connections of this generator in detail. The current from the trolley passes through the magnetic blow-out *X* to the main terminal *A*. When the gauge hand touches the cutting-in contact *I*, current flows through the fuse *H* and the relay magnets *W* and *V* to the contact *E*, thence through the gauge hand to the contact *I*

and to ground. Magnet *V*, when energized, closes this circuit from *E* to *D*, thus short-circuiting the gauge hand and its contact *I*, conseqently when the hand moves away the relay circuit still remains closed. When the magnet *W* was energized contacts *F* and *G* were joined and another circuit established through the fuse *K* and the magnets *Y* and *Z* to ground. These magnets when energized close the pump motor circuit between terminals *A* and *B* by means of *CC*. As the pressure in the reservoir rises, the gauge hand approaches the contact *O*, and upon touching it the current through the magnet *W* flows via the contact *O* to the contact *E*, thereby short-circuiting the magnet *V*. This opens the relay circuit between *E* and *D* which demagnetizes *W*, consequently the circuit through *Y* and *Z* is opened between *F* and *G*. The demagnetizing of *Y* and

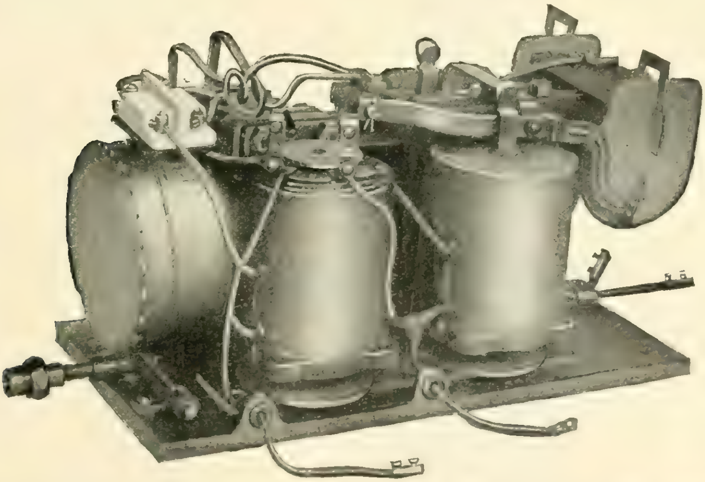

FIG. 32—A MAGNETICALLY OPERATED GOVERNOR SO DESIGNED THAT ONE GOVERNOR CANNOT CARRY THE LOAD OF ALL THE PUMPS ON THE TRAIN

Z permits the bar *CC* to open the motor circuit at the terminals *A* and *B*, thereby stopping the compressor. When the motor-switch operating circuit is closed between *F* and *G* it will be noticed that the equalizing wire is also grounded; consequently so long as any one of the relay circuits on a train remains closed the equalizing wire forms a ground connection for the switch-operating circuits of the other governors. Thus all of the compressors are cut-out together when the governor which is set the highest cuts out.

Fig. 34 shows a governor auxiliary valve in section. This is a device used in connection with any simple governor to cause it to

cut-in immediately after the starting of any pump of a multiple unit train. Thus it accomplishes the purpose of the multiple unit train governor described on page 448, but without the use of a balance wire or any other special connection, either electric or pneumatic, through the train. It is connected in the branch pipes leading from the main reservoirs to the reservoir line through the train, the outlet *R* being toward the reservoir. The diaphragm chamber *D* and that of the slide valve 25 are unobstructedly connected to the main reservoir line. The chamber *C* above the diaphragm 18, is connected to the main reservoir through the chamber *A*, which is separated from the main reservoir line by the check valve 30. If the pressure in *D* is slightly greater than in *C* the movement of the diaphragm will lift the valve 16, thereby opening the chamber *E* to the atmosphere through passages *f*, *h* and *y*. When the pressure in *C* is equal to that in *D* the valve is closed and the air in *E* cannot escape. The closely fitting piston 24, which controls the position of slide valve 25, separates the chamber *E* from that of the slide valve. Air, however, can leak by this piston so that when the valve 16 is closed the pressures on both sides are equal and the spring 22 forces the piston and valve into the position shown. In this position, air

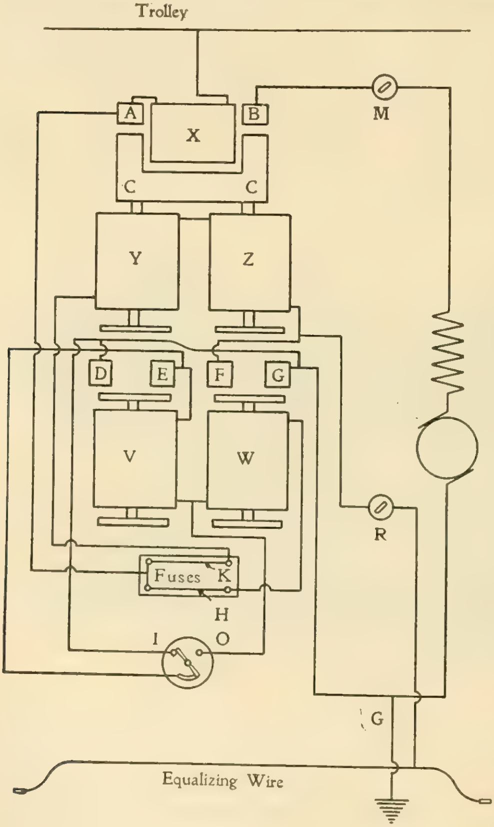

FIG. 33—CONNECTIONS FOR A SPECIAL GOVERNOR FOR MULTIPLE UNIT SERVICE

from the main reservoir passes through the passage *e*, the chamber *l* in the slide valve, and the port *g*, to the governor and holds its switch open if the pressure is sufficiently high. When a compressor on another car is cut-in by its governor it raises the pressure in the reservoir line above that of the main reservoir on the other cars, thereby opening the valve 16 and exhausting the air in chamber *E*. The preponderance of pressure now on the underside of the piston 24 moves it and the valve 25 to the upper end of its stroke. In this position the passage *e* is cut off from *g* and the chamber *m* connects *g* to the passage *x*, which leads to the atmosphere. The escape of all the air pressure from the governor causes it to cut-in its compressor at once. Thus the cutting-in of one compressor

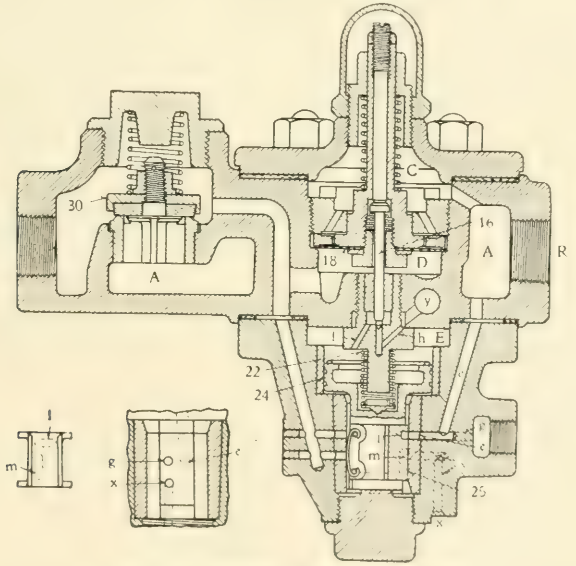

FIG. 34—GOVERNOR AUXILIARY VALVE

causes all the other compressors on the same train to cut-in at once. In this operation each governor acts independently, but as air cannot flow from the reservoir line to any of the reservoirs the compressor which cuts out at the highest pressure has to supply the excess pressure to the reservoir line and its own reservoir only. As soon as a compressor raises the pressure in the reservoir to that of the reservoir line, valve 16 closes, the pressure equalizes on both sides of the piston 24 and it is moved to the lower end of its stroke, thereby admitting reservoir pressure to the governor that it may cut the compressor out of action when the maximum pressure is attained.

FACTORY TESTING OF ELECTRICAL MACHINERY—XVIII

By R. E. WORKMAN

INDUCTION MOTORS—Continued

IN making a locked saturation test as described in the preceding issue of the JOURNAL the following precautions should be considered:

Precautions to be Observed—In the case of small motors, two-hp and below, the torque required to overcome the bearing friction often will be relatively large in proportion to the total torque developed by the motor and should be eliminated. The following methods of doing this will be found satisfactory:

First. With the power applied and the scales nearly balanced, bear heavily on the end of the brake arm directly over the scales, then remove this pressure quickly but steadily without jarring the brake arm. The slight up and down motion of the scale platform will generally be sufficient to remove the effect of the bearing friction.

It will be well to apply this method of reading the scales to motors of all sizes as it secures a greater uniformity of bearing conditions.

The pressed-down reading on the scales should be noted with the power off. This will give some idea of the static bearing friction and should be deducted from the very low voltage points in case it is relatively large.

Second. The torque may be measured by a spring balance, reading it while being slowly raised and then again while being slowly lowered. The balance should be read each time as the brake arm passes the horizontal position. The average of these two readings will be the torque developed by the motor.

At the high voltages the motor may become very hot and it is often necessary to loosen the brake and let it run for a short time to cool. Such excessive heating of the motor is not only injurious to the insulation, but prevents the determination of the correct curve owing to the changes in resistance due to the heating. For this reason it is advisable to take the high voltage points first.

The heating of the motor causes a decrease in the torque produced by a given voltage, since the resistance of the primary is increased, thereby reducing the effective impressed e.m.f. The heating of the secondary tends to increase the torque but this effect is more than offset by the heating

of the primary. Each reading must be made as quickly as possible, throwing the current on and off between readings. If the temperature should rise too high, the motor should be cooled before continuing as stated above.

The speed of the generator furnishing the power, should not be allowed to fall over ten per cent. else the current and the torque will be too high. In the case of very large motors the generator speed should be increased before the power is applied.

If it becomes necessary to run the motor between readings, care

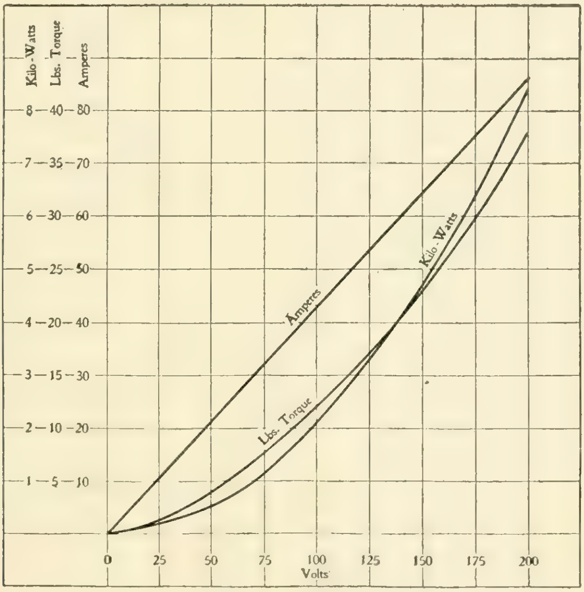

FIG. 83—LOCKED SATURATION CURVE OF A 200 VOLT, 60 CYCLE, EIGHT POLEA FIVE HP, TWO-PHASE INDUCTION MOTOR

should be taken to clamp the brake on the brake pulley at the same place each time. This precaution is scarcely necessary in the case of a cage-wound motor, but with one that is phase-wound, it is absolutely necessary, since the variation of the primary with respect to the secondary by an amount of only one slot will often cause a 25 per cent. variation in the torque for the same voltage. This is due to what are commonly called dead points which are due to the fact that it is impossible to get a phase-wound secondary to act as if it were short-circuited at every point. In any phase-wound secondary there will be some local currents and these will

vary with different relative slot positions of the two parts of the motor.

There is no good method for calculating this difference in torque from the secondary position and it is therefore necessary to make this test on a position of maximum torque since this most nearly corresponds to a universally short-circuited secondary winding. It is, however, advisable to take a few readings on the minimum torque position since this represents the worst condition under which the motor may start. If there is a very great difference in these torque readings the motor windings should be investigated.

The man holding the voltage will give the signal when the voltage is of the desired value; the readings of this phase are now taken and the switches thrown to read the next phase. If now the voltage does not read exactly on this phase as it did on the first one, it should be read as it is and not altered to the previous value, unless the difference is due to line variations, in which case the difference will be large and the cause easily recognized. Generally speaking, this difference will be due to either the transformers or the motor, and if it is slight, the error will be of no consequence. The average of the voltages will be the final voltage.

Working up Results—The torque readings are computed exactly as in the brake test of direct-current motors; the tare of the brake in pounds is subtracted from each reading, and the result multiplied by the length of the brake arm in feet. The leakage current or the percentage of the full-load current expended in ovrcoming the e. m. f. due to the leakage flux, is found, for any current, by calculation, either analytically or graphically by a diagram, to be described later.

Fig. 83 shows the locked saturation curves for the 5-hp motor whose running saturation curves are given in Fig. 82.

In the case of a motor with a phase-wound secondary, the secondary current is read and plotted with the other curves.

EDITORIAL COMMENT

A Modern Utopia

Plato portrayed an ideal Republic and others have followed his example by presenting various Utopias as welcome substitutes for the World as it is. Ideals are significant—they point the trend of men's purposes, they give the keynote of life.

There was a fundamental aspect in common among the "Utopias men planned before Darwin quickened the thought of the world. Those were all perfect and static States, a balance of happiness won forever against the forces of unrest and disorder that inhere in things. Change and development were dammed back by invincible dams forever. But the modern Utopia must not be static, but kinetic, must shape not as a permanent state but as a hopeful stage, leading to a long ascent of stages. Nowadays we do not resist and overcome the great stream of things, but rather float upon it. We build now not citadels, but ships of state."*

Not static, but kinetic; not rest, but activity; not achieved perfection, but continuous development. Such is the change in the ideas of life which science has brought about, and such are the ideals of applied science in the domain of engineering. In electrical engineering this new principle is dominant. Its whole development has been within a lifetime, and yet apparatus and methods have repeatedly become obsolete. Someone has found that electrical apparatus is out-of-date in three years—so persistent is the progress.

It requires a bold imagination to venture to predict the future definitely. One is scarcely safe in predicting that anything is impossible—unless perchance it violates some fundamental principle, such as the law of the conservation of energy.

Progress is our present actuating force. Changes are rapid in industrial and commercial and social affairs—often keeping well nigh apace with those in applied electricity. It often seems that the next step will be the last one—the desired end will have been reached. But it is soon lost sight of in a renewed endeavor.

Those who are learners in the technical schools or in the school of experience are preparing for a future which will be changing, progressive. The problems which they may encounter

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*From the first page of "A Modern Utopia," by H. G. Wells.

are not recorded in any text-book nor have they yet been solved. Mere memoriter nor the ability to repeat what one has done before will avail. There must be the ability to translate from the known to the new. And the modern Utopia is not a final achievement, but a progressive advance.

Engineering forces are not static, but kinetic; engineering work is never completed, but the ideal is continuous progress; and the leaders must be men whose horizon continuously widens.

Chas. F. Scott

Specifications For a Road Engineer

The articles by Mr. Shipman in the June number of the Journal, and by Mr. Stephenson in this issue, illustrate very aptly the difficulties often encountered by the construction engineer, as well as the qualities essential to successfully meet the exigencies of road work.

For the benefit of the young man who contemplates entering the field as an engineer on outside work, a few words as to the sort of a man wanted and what he should know will not be amiss. As we are not, for the time being, considering the requirements for a vice-president or a general manager, it should be stated that the road man needs only a reasonable amount of the elements needed in many another calling, supplemented by a specialized knowledge of the work in hand.

It is desirable, though not essential, that he should have a technical education.

He must be thoroughly familiar with the design, construction, and operation of the apparatus to be installed.

No amount of theory will make up for the lack of detailed information as to how machinery is put together, and the operations necessary to prepare the parts. Many a young engineer has been stumped by a mechanical detail which has been worked out before his eyes in the shop time and again, but which he has failed to make his own through lack of observation.

A certain amount of dexterity in the use of tools will be found very valuable, both in doing work oneself, and in directing others. It is necessary to know a good job by sight and the length of time required for its performance.

System is another useful asset in the make-up of a construction engineer. Nothing is so discouraging as work carried on in

a disorganized fashion. Exact records and checks should be kept of shipments received, and the work should be laid out so as to go along smoothly as a whole, due account being taken of the cost.

The question of reports, both engineering and of expense, should receive careful attention, and it should never be forgotten that it is from his letters that an outside man is largely judged.

The construction engineer represents his company, and he has to do with outside interests. He needs, therefore, qualities which may not be essential for inside work, and these in the opinion of the writer are three in number:

1st. Perseverance—This will in time, as in everything else, bring all needful, special knowledge.

2nd. Ingenuity—Ability to apply the information acquired in time of emergency.

3rd. Tact—The ability to get along with people from the workman to the general manager may be largely inborn, but also it can be cultivated, and the best equipped engineer will fail if he does not possess this trait.

R. L. Wilson

Experience

"You can teach a man everything except experience—that he must get for himself," remarked a man whose business it is to organize and direct a large number of men.

One must have experience of his own, but he may profit by the experience of others. In fact much of our knowledge which we consider as absolute truth and fundamental principles is really the formulated experience of others. Professor Franklin said recently, "Sometime ago in talking with a practical engineer on the teaching of physics, I stated that in my opinion the ultimate object of the teaching of physics to technical students is to lead the young man by a shortened route to that familiarity with physical things which is possessed by such a man as John Fritz."

An amusing incident occurred recently which shows how hard it is to transmit experience. An apprentice left the works to install some street railway apparatus. Like the rich man in the story of Lazarus he wanted to send back from his place of torment some words of warning to his brothers. And, more fortunate than his richer prototype, he was able to write to his chum in the works. The letter went further than intended and

was printed in the February JOURNAL. This letter advised its recipient to get experience. Its author had neglected his opportunity.

But human nature remains the same, the brothers would not be persuaded.

An apprentice in commenting upon the JOURNAL wrote this: "To me the most valuable features are the articles on practical subjects, e. g., 'Modern Practice in Switchboard Design.' The least valuable are such things as childish letters purporting to be from one apprentice to another.

Referring again to experience, it is seldom that one can find it so terse and fresh and interesting and suggestive as in the stories of construction engineers in the preceding and the present issues of the JOURNAL. There is a good deal in what they have written, but there is much more between the lines. The first gives specific instances, the second shows the prevalence of the unexpected and the sort of qualities which make for success.

CHAS. F. SCOTT

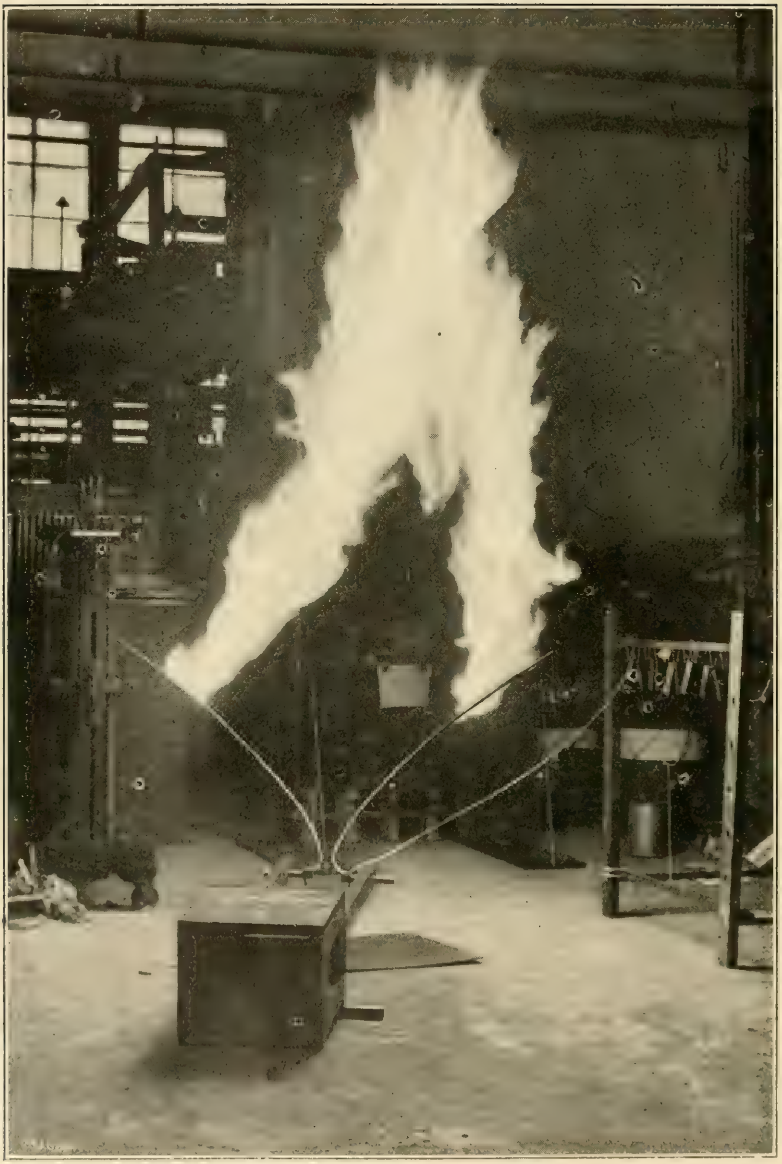
The Card Index

Until recently it has been the custom of the JOURNAL to print a monthly index, suitable for card filing, of the subject matter contained in each preceding number.

In the last issue announcement was made that the index for May would be printed on a separate sheet and could be had upon request.

To date 24 requests have been received. Evidently JOURNAL readers do not care for the index, and the space can be appropriated to better use.

If sufficient applications are received, the index will continue to be printed on a separate sheet and mailed to all who wish it, postpaid.



DISCHARGE OF HORN TYPE LIGHTNING ARRESTER DIRECT FROM A 250 KW. 20,000 VOLT TRANSFORMER

THE
ELECTRIC JOURNAL

VOL. II AUGUST, 1905 No 8.

THE MAN OF THE FUTURE

FRANK H. TAYLOR
Second Vice-President of the Electric Company

The final meeting of The Electric Club before the summer intermission was addressed by Mr. Frank H. Taylor on "The Man of the Future." His remarks were evidently intended to encourage the young men of his audience who had recently graduated from college—both those who had adopted a business career and those who had specialized in electrical or mechanical engineering and were now in the midst of their apprenticeship course. He struck a hopeful note for the man of twenty-five.

I AM of a generation that is now taking the severe burden of business affairs. You are of the succeeding generation. Upon you the load of responsibilities will descend and to you belongs the promise of the future.

We live in a world where things repeat themselves, an old world where men have lived and wrought through many generations. The great fundamental truths remain as unshaken today as they did thousands of years ago. Some of these were taught us at our mother's knee, and truths they were, are and ever will be. The fundamental laws of honest business have not changed. Yet every morning brings a new day and every generation has for its own, new opportunities as well as new requirements.

In a certain sense every artificial thing in the world shall pass away. I could not have prospered if I had followed the business methods of my grandfather. He did well as a farmer where no man of his class can now make a living. Neither could I have followed tanning as it was done by my father before the application of modern chemistry to that industry. During a business life of twenty-eight years I have seen a great revolution from the prosperous individual business to the small corporation, through many steps to the great modern organization of today, which may be said not to have existed at all when I left college. We see, therefore, that

the methods of only a few years ago could not continue unchanged. While I make no pretense to read the future, yet we may be well assured that your generation will be obliged to greatly modify our large corporations as they stand today. The indications of a new adjustment will be the signal for new leaders to appear.

As history has judged other generations by the work of its leaders so it will judge yours. Let us hope there may be one at least of these leaders here tonight, but I fear we can do or say very little to create such men. Those with whom I have come in contact were men who discovered their own masterful qualities and were not selected by any one. There is always something indescribable about men of power, and it pays to be often in their presence. Fearless, simple, direct, bearing their heavy burdens without complaint, they deal with the tremendous problems of their time. There is, too, a real joy in leadership that no man with the necessary genius ought to forego. Some day the trumpet note of your generation will sound and your leaders will spring into their proper places. They will force themselves forward in this or in other companies, and will naturally take their rank, welcomed alike by younger and older.

There should be among you the keenest interest to detect your leader. As you watch and listen some one of you will catch the rhythmic note of the new day. That which is in error will be brought to light. Things as they stand today are not final and a new leader will direct you by effective steps, to the needs of your time. I do not look for a revolutionist but for one who in a patient, masterful, able manner will lead into safer and sounder paths. We cannot all be great but it is honor and joy enough for most men to be the loyal and faithful captains without whom the work of the great general must go for naught.

There is no reason why any of us should fail in efficient service provided we keep just a few true things in mind. My observation has extended over a time long enough to assure the man of twenty-five that by a diligent and intelligent pursuit of the work that lays at his hand, he will prosper. Look forward to your careers with joy and cheerfulness, with courage and confidence. Lead simple, normal, happy lives ready at any moment to grasp firmly the first clear opportunity for wider experience.

Do not feel as if you were undergoing a mysterious kind of punishment during your apprenticeship. Live here as if it were your home. You will get the needed experience of life just where you

are. Your intellectual development like your physical development does not depend on the amount and variety of food you take in. A sound digestion is the essential thing. Above all things your experiences need to be digested properly.

I recall that I went at my apprentice work carefully and deliberately. I did first one disjointed thing and then another, and finally I was rewarded for the thought I gave to the subject by finding that these separate things settled themselves in their proper places and I caught the essential binding link so that all that went on around me became part of a complete scheme, the unity of which was revealed to me.

I think if I were an apprentice in a great company's works I should hunt up some place where work had congested and I would ask for a chance at the job. I would master it in such a way that I would forthwith be intrusted with a continuance of duties that would tax my resources and insure my growth. A mark is put upon such a man.

Continuing growth is the essence of success. Keep growing so long as you remain on this earth. A power to grow continually even if it be gradually is the first requisite for a successful life. To grow we must keep humble and not think we know it all. Next is the importance of keeping in the current of vital events. Swim always in the broad river in company with men bigger than yourselves. Be generous enough to recognize the better man. Keep out of the pleasant eddies of life or you may circle back to the worn out methods of your grandfather.

You will always need exact knowledge but let it be broad. I would not undervalue the extreme specialist but as a leader he is apt to be too one sided. The class leader at college sometimes turns out to be a misfit in later life. I saw one once who seemed to be strong but in action he was like one driving wheel on a locomotive that was a little larger in diameter than its fellows! On the other hand, you must not remain in the background, constantly playing safe. With your fresh minds and fresh ambitions you need a good share of daring to succeed. Come out in the open and make a few blunders, take your licking, and thereby gather lessons for the future. Some things come to you at college easily—on a silver plate; you enjoyed the incense of popularity and opportunities were made for you. Do not expect and do not welcome these experiences in your business life, such worship is dangerous after the college days are over.

A man who had succeeded in working college men said that he could always count on these men to be absolutely loyal, to be ready to volunteer for extra duty and work eighteen hours a day when occasion required it. To inspire such loyalty he must himself be a genius as well as a leader.

I anticipate your generation will do better than ours in its relation to our broader national life. We have taken our public duties too lightly. You must make up your minds to stand up more firmly for good government, for a proper recognition of the claims of social and religious life, for a just and sympathetic treatment of labor. The sharp man of affairs will be discredited in the future. As President Butler said at a banquet in Pittsburg, "We don't need sharp men. We need broad men sharpened to a point."

With you as with us wealth will be somewhat a matter of accident. Much of it will come from methods akin to gambling, and of all things gambling is unsportsmanlike and leads more often to disaster than to success. I do not address you as men who wish to win by doubtful methods. Don't be ambitious for wealth as such. Don't barter your life for it. It is beyond your control. Manage your future organization so that the owner of the individual will be better recognized. Provide for a business condition where all competent men can develop wholesome, robust lives and can find happiness and contentment in their work. In order for the full development of your own powers, as well as those of others be generous to those with whom you work. Never pull a man back in the race. Rejoice to see the best man win.

Some answers found in your question box interested me. Nearly every suggestion to improve the Club could have been carried out by the exercise of some determined, sustained effort on the part of the man who made it. Some were too ambitious—one man wanted the Club to establish a cafe at which he could always get a real beefsteak instead of the worn out insulating compound that his landlady served to him. Some were very critical—one thought the management would have to run things a good deal better before he could be coaxed out of his easy chair from behind his pipe.

Some consolation is due the non-aggressive man. Let him remember the farmer who said he could never understand why they talked so much about taking the bull by the horns. He reckoned if you took him by the tail you would be going about as fast and be keeping close enough: then you would see what was going on and if you had to do it you could let go any minute.

CENTRAL STATION TRANSFORMER TESTING

WILLIAM NESBIT

SUCCESS in the operation of a central station depends in a large measure upon the excellence of the transformers, for they determine to a large degree the satisfaction and reliability of the service and the cost of operation. Transformer iron loss which is continuous for 24 hours a day, calls for a supply of energy which is responsible for no small part of the fuel consumption. A reduction of one half in the iron loss of transformers might add handsomely to the profits at the end of a year.

The importance of tests to determine the regulation and losses in transformers scarcely needs to be emphasized. The following article outlines a series of simple tests.

Assume that a central station superintendent wishes to test some 10 kw, 60-cycle, 2 100 or 1 050-volt primary, 210 or 105-volt secondary transformers. The following tests should be made in the order given.

1. Copper Loss Test.
2. Regulation Test.
3. Ratio Test.
4. Iron Loss Test.
5. Temperature Test.
6. Insulation Test.

COPPER LOSS

Copper loss takes place only when the transformer is delivering power and varies as the square of the current. It is the amount

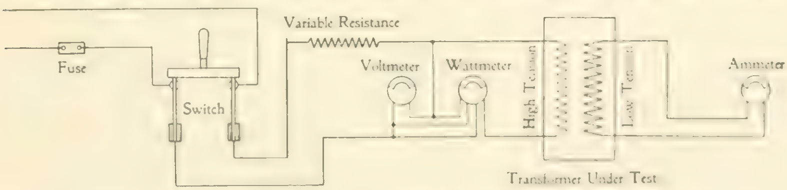


FIG. 1—CONNECTIONS FOR MAKING A COPPER LOSS TEST ON A TRANSFORMER

of power expended in forcing current through the windings. The copper loss increases with the temperature at the rate of 1 per cent. increase for every 2.5 degrees C. rise in temperature. Copper loss readings are usually taken with the windings at a temperature of approximately 25 degrees C. Fig. 1 shows the arrangement of the instruments for this test.

The low tension side of the transformer is short-circuited through an ammeter and a voltage applied to the 2 100-volt winding sufficient to force full-load current through the ammeter. The current in this case is 10 000÷105 or 95.2 amperes. The required voltage which is known as the impedance voltage, may

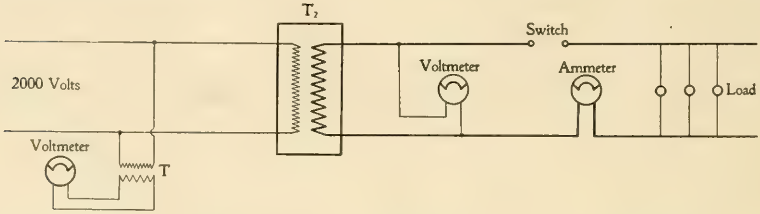


FIG. 2—CONNECTIONS FOR MAKING A REGULATION TEST ON A TRANSFORMER

vary from two to six per cent. depending upon the size and design of the transformer. We will assume that the following readings were obtained on the transformer in question:

Serial Number	Date	Impedance Volts	Cycles	Secondary Amp	Wattmeter Reading	Temperature
36	1-2-05	66	60	95.2	190	25.6°

REGULATION TEST

The regulation of a transformer with a load of a given power-factor is the percentage of difference, based on the full-load voltage, between the full-load and no-load secondary voltages with a constant applied primary voltage. It may be ascertained by ap-

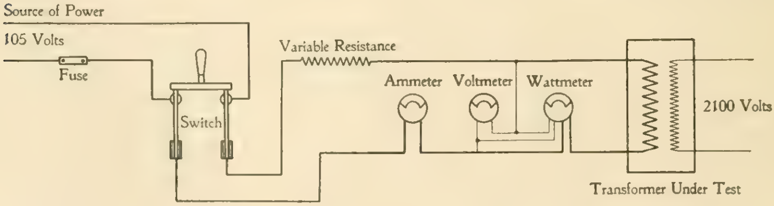


FIG. 3—CONNECTIONS FOR MAKING AN IRON LOSS TEST ON A TRANSFORMER

plying full-load to the transformer and noting the secondary voltage, then removing the load and noting the secondary open circuit voltage. For both these readings the primary voltage must be held at a constant value. The primary voltage may be

observed on the voltmeter shown connected to *T*, Fig. 2. It is difficult to get satisfactory readings in making this test for the reason that the rise in voltage between full-load and no-load is usually very slight.

Assume the following values to have been taken on the 10 kw transformer.

NO-LOAD

Volts T_1	Volts T_2	Volts Difference.
105	105	0.
105	105	0.
105	105	0.
	FULL LOAD	
105	103.0	2.
105	103.1	1.9
105	103.1	1.9

$5.8 \div 3 = 1.93$ volts

or approximately 1.9 per cent. regulation.

The drop in the secondary voltage will be very much greater with an inductive load, such as arc lamps or induction motors, than it will be with incandescent lamps.

Regulation tests for loads having any power-factor may be made in the same manner as given above by substituting arc lamps for some or all of the incandescent lamps. In this case it will be necessary to use either a wattmeter or a power-factor meter if it is desired to determine the power-factor of the load.

RATIO

The ratio of the transformer is tested when the regulation test is made.

IRON LOSS TEST

The iron loss in a transformer represents the power required to magnetize its core sufficiently to give normal secondary voltage. This loss is practically constant at all loads for a given voltage but varies with the frequency of the circuit. The lower the frequency the greater will be the iron loss, and vice versa. The connections to the various instruments in making this test are shown in Fig. 3. Care should be taken that the frequency of the supply circuit is exactly 60 cycles and by changing the variable resistance, that the voltmeter reading is brought to 105.

With the frequency and voltage both normal, take simultaneous readings of the ammeter and wattmeter. Assuming that the ammeter indicates 1.7 amperes and the wattmeter indicates 130 true watts, we then have the following record:

Serial Number	Date	Volts	Cycles	Amperes	Apparent Watts	True Watts	Temp
36	1-2-05	105	60	1.7	178.5	130	25° C

The wave form of the applied e. m. f. affects the iron loss. A flat top wave gives a greater loss than a peaked wave and vice versa. A variation in iron loss of 5 to 10 per cent. may be obtained by testing on currents having different wave forms. The apparent watts are found by multiplying the current taken by the voltage impressed.

TEMPERATURE TEST

Manufacturers testing a great many transformers, use a method known as the opposition or bucking method. This method requires power equivalent only to the total losses in the transformers being tested. Central stations, however, will find the following method more simple. See Fig. 4.

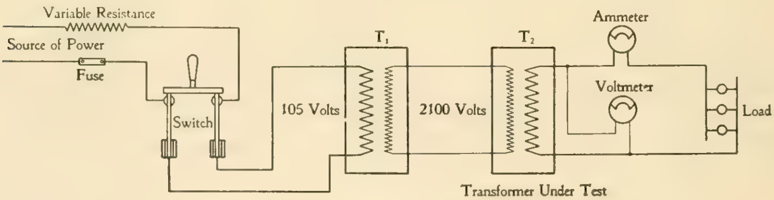


FIG. 4—CONNECTIONS FOR MAKING A TEMPERATURE RUN ON A TRANSFORMER AVOIDING THE HANDLING OF HIGH POTENTIALS

Two transformers are used having their high voltage sides connected together. 105 volts is applied to the low voltage winding of one of the transformers, T_1 and about 100 volts is obtained from the low tension winding of the other transformer, T_2. Lamps are lighted from transformer T_2 until the ammeter indicates full-load. The voltage is simultaneously varied by the use of the variable resistance until the voltmeter on T_2 indicates the proper full-load voltage. It will be observed that transformer T_1 carries the losses of T_2 as well as the load on T_2. Transformer T_1 will there-

fore get slightly warmer than transformer T_2. Thermometers are now placed on the coils and the iron of T_2 and the readings are noted.

Thermometer readings are taken of the temperature of the oil, iron, coils and external air, as follows:

Serial Number	Time	Volts	Amperes	Air	Iron	Coils	Oil
36	5.00 P. M.	97.7	95.2	25°	29°	28°	28°
36	8.00 A. M.	97.7	95.2	22°	64°	66°	65°
Temperature rise above air					42°	44	43°

Readings may be taken every hour if desired and a curve plotted showing the rate of the temperature rise. Usually ten to fourteen hours are required for the temperature to reach its maximum value.

If suitable instruments are available for taking resistance measurements of the high tension and low tension windings both before and immediately after the temperature test, the temperature rise may be calculated from the increase in the resistance.

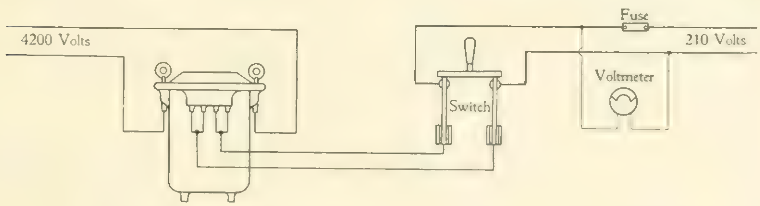


FIG 5—OVER POTENTIAL TEST ON A 2 100-105 VOLT TRANSFORMER

The increase in resistance method gives the average temperature which is usually slightly higher than the thermometer values representing the temperature of the outside of the coil. The thermometer method, being the simpler, is probably better adapted to central station testing of small transformers.

INSULATION TEST

This test is important not so much on account of the danger of the interruption of the service should the insulation be weak, but because of the danger to human life. Newspaper notices chronicling the death of persons killed by touching lamp sockets

which are wired to transformers having defective insulation, are of frequent occurrence.

Complete insulation tests consist of insulation resistance, over-potential, and puncture tests.

INSULATION RESISTANCE TEST—The insulation resistance test is made by the manufacturer to ascertain the general condition of the insulating material used in the transformer. Insulation resistance varies so greatly with the temperature of the winding that this test is of little value in showing any real characteristic of the insulation of a transformer.

OVER-POTENTIAL TEST—This test is made for the purpose of testing the insulation between adjacent turns and also between adjacent layers of the windings. It usually consists of applying a voltage two to four times the normal voltage to one of the windings with the other winding open circuited. If this test is to be made on the transformer in question, at twice its normal voltage, 4 200 volts may be applied to the 2 100 volt winding, 2 100 volts to the 1 050 volt winding, 420 volts to the 210 volt winding, or 210 volts to the 105 volt winding. As 210 volts is the safer to handle and usually accessible, it should generally be used. This over-potential should be applied for about five seconds, as shown in Fig. 5. The 2 100 volt winding receives 4 200 volts due to the ratio of the transformer. A frequency of at least 60 cycles should be used in making this test—the higher the frequency the less will be the amount of current required to make the test.

PUNCTURE TEST—This test is made to determine the strength of the insulation between the high tension and the low tension coils and also between the coils and the core. In general the following test is made: 10 000 volts alternating e.m.f. is applied between the high tension and the low tension windings with the low tension winding connected to the core and the case, and 2 500 to 4 000 volts (varying with different manufacturers) alternating e. m. f. between the low tension winding and the core and the case.

For making all insulation tests it is desirable to have a portable testing transformer wound to give various voltages between 100 and 15 000 volts. Such testing transformer can be purchased from manufacturers and consist of a small transformer mounted on wheels with necessary switching apparatus so that the voltage may be easily changed. In the absence of a regular testing transformer six ordinary lighting transformers thoroughly insulated

from each other and connected in series, as shown in Fig. 6, may be used, though the fact that this method requires six to nine transformers to test one renders it more practical for the central station having considerable testing to do to purchase a special testing transformer. Transformers A, B and C shown in this sketch are simply used to insulate the high voltage circuit from the source of power and to limit the strain to which the insulation of the six testing transformers are subjected (by reason of their high tension windings being all connected in series) to 6 000 volts. These three transformers may be dispensed with and the high tension windings of the remaining six connected in series. Grounding the middle point of this series will relieve it of excessive strains. If this ground connection is made it will be

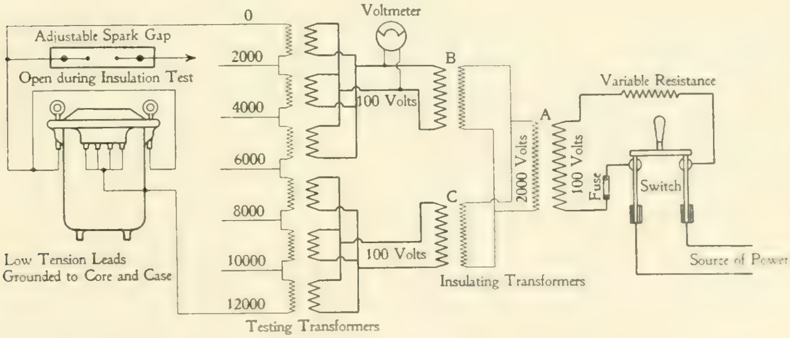


FIG. 6—CONNECTIONS FOR MAKING AN INSULATION PUNCTURE TEST FROM ORDINARY LIGHTING TRANSFORMERS

necessary to thoroughly insulate all the transformers including the transformer being tested, from the ground.

Before proceeding with the insulation test it is desirable to insert an adjustable spark gap between the 10 000 volt leads of the testing transformers so as to make certain that the voltage strain from the testing transformers does not exceed that produced by 10 000 volts.

Below is given the distance which various voltages having a sine wave, will jump through dry air between sharp needle points. If the voltage has a peaked curve such as is quite commonly obtained from generators of the inductor type, a given voltage will jump a greater distance than that given in the table

and consequently produce a greater strain on the insulation of the apparatus under test.

Volts	Needle Point Sparking Distance
5 000	0.225 inches
10 000	0.470 "
15 000	0.700 "
20 000	1.000 "
25 000	1.300 "
30 000	1.625 "

Space the needle points on the spark gap 0.47 of an inch apart, connect the spark gap across the 10 000 volt circuit and insert all of the variable resistance in the primary circuit; now throw in the line switch and gradually cut out the variable resistance until the current jumps across the gaps and note at what deflection on the voltmeter this jumping occurs. This will be the deflection to use in making tests on transformers for a 10 000 volt strain. The actual voltage may vary above or below 10 000 volts according to the form of the wave but the transformer will receive a strain equivalent to 10 000 volts, sine wave. If the high tension voltage is calculated from the voltage on the voltmeter and the ratio of transformation of the testing transformers, the transformer under test is liable to receive a strain equivalent to 12 000 or 13 000 volts, should the wave form of the generator supplying the current be peaked. Furthermore, if a spark gap is not used there is always danger of making a mistake in calculating the testing voltage or in connecting up the testing transformers so as to give a higher testing voltage than intended. In making this test, both high-tension leads of the transformer under test should be connected together and to one of the 10 000 volt leads. Connect all the low-tension leads together and to the other 10 000 volt lead with the low-tension leads also connected to the core and the case. Disconnect the spark gap, throw in all the variable resistance, throw in the line switch and cut out the variable resistance until the voltmeter indicates the same deflection as was indicated when the spark gap was ruptured. Hold the voltage at this point for about five seconds; then cut in the variable resistance and open the line switch.

The insulation between the low tension winding and the core may be tested in a similar manner by setting the spark gap for the required voltage and changing the connection to the test-

ing transformers. If there is a considerable discrepancy between the spark gap method of determining the voltage and the voltmeter reading multiplied by its ratio of transformation, investigation should be made at once.

EFFICIENCY

This is the ratio of the power delivered by the secondary to the power taken in by the primary. The efficiency of the transformer under consideration is as follows:

Full-load.................	10 000 watts.	
Iron loss..............	130 "	
Copper loss............	190 "	
	10 320 watts input to primary.	

10 000÷10 320=96.9 per cent. efficiency at full-load.

Three-quarters load.......	7 500 watts.	
Iron loss..............	130 "	
Copper loss............	107 "	(9/16 of 190 watts)
	7 737 watts input to primary.	

7 500 : 7 737=96.9 per cent. efficiency at three-quarters load.

One-half load............	5 000 watts.	
Iron loss..............	130 "	
Copper loss............	47.5 "	(¼ of 190 watts)
	5 177.5 watts input to primary.	

5 000÷5 177.5=96.6 per cent. efficiency at one-half load.

One-quarter load.........	2 500 watts.	
Iron loss..............	130 "	
Copper loss............	11.9 "	(1/16 of 190 watts)
	2 641.9 watts input to primary.	

2 500 : 2 641.9=94.6 per cent. efficiency at one-quarter load.

It will be noted that the iron loss remains constant at all loads but that the copper loss varies as the square of the load.

As copper loss and regulation remain the same in all transformers of a given design and size, it is only necessary to make these tests on one transformer of each capacity and type. This is also true in making temperature tests, provided the iron loss is not excessive. The most important tests and ones which should be made frequently are, insulation, and iron loss tests.

THE HANDLING OF ELECTRICAL INSTRUMENTS IN RELATION TO THEIR ACCURACY

H. B. TAYLOR

IN using electrical measuring instruments and in setting them up for making a test, there are certain points to be considered which are likely to be overlooked by men who have not frequent occasion to use them. This is especially true where a number of instruments are to be used on one test. In the effort to put all of the instruments in places where they can be conveniently read and at the same time have other apparatus within easy reach, there are many chances of placing some of the instruments in locations where their calibration will be temporarily affected by their influence upon each other or by the effect of some other piece of apparatus or part of the conducting circuit.

THE STRAY MAGNETIC FIELD

A knowledge of the principle upon which an instrument operates, the location of its winding and of its magnet, if any, should enable the person using it to judge whether a particular location is suitable. Some instruments are quite susceptible to external influences, while with others, scarcely any attention need be paid to the location of stray magnetic fields. So many kinds of instruments are in use that it would not be possible in a short article to discuss the different types, or the various capacities of those of any particular type, but it may be said in general that there are more opportunities for error in measuring heavy currents than in measuring small ones. In direct-current work there may be disturbing influences entirely apart from the apparatus in use on the test; such, for instance, as the field of a motor or a generator or a nearby bus bar carrying heavy currents. Instruments containing permanent magnets will, if placed too close together, influence each other. The natural tendency is to place them in almost the worst possible position; that is, side by side. A space of from two to three feet may be taken as a safe distance to allow between direct-current meters of the ordinary portable type. When space is very limited, two instruments can often be brought closer together without causing trouble, by placing one of them with its scale inverted with respect to the other, so that the neutral parts of the magnets are nearest to each other and the pole pieces

as far apart as possible. For the most accurate results even the earth's magnetic field must be taken into account, the maximum possible variation in reading from this cause being usually a little more than one-tenth of one per cent.

With the exception of the astatically wound instruments which have recently been introduced in portable form, electromagnetic instruments designed for use on both alternating and direct currents, when used on direct current must be read with the current first in one direction and then in the other. The average between the direct and reverse readings gives the true reading if the scale is uniform. If all external magnetic fields acting upon the instrument are independent of the current in the circuit the reversal can be made at any convenient point, but if there is a probable influence from the conductors or apparatus in circuit, it is best to make the reversal at the terminals of the instrument in order to correct for all stray fields at once.

Alternating and direct-current ammeters and wattmeters made for heavy currents are likely to have only a turn or two in the coils carrying the main currents. It is then a matter of importance in connecting them, to bring the leads to them in such a way that they do not form a loop which can set up a magnetic field aiding or opposing that of the instrument winding. The best way of doing this is to keep them very close, preferably twisted together for some distance away from the meter. With alternating currents there is less chance of disturbing influences apart from the apparatus in the circuit than with direct currents because only alternating fields at the frequency of the circuit and having a fairly constant phase relation with it can affect the instruments. This practically limits the stray field influence to that of the instruments and other apparatus in the circuit upon each other. It will be remembered, however, that alternating and direct-current instruments are more susceptible to influence from conductors than are direct-current instruments.

The foregoing remarks do not apply to induction instruments as the principle upon which they are made is such that a stray field could scarcely enter in a way that would affect them. Neither do they apply to electrostatic and hot-wire instruments. There are so many things which tend to prevent accurate work with the latter two classes of instruments that they are little used in ordinary testing. Their most valuable property is that the voltmeters are independent of the frequency. Electrostatic

voltmeters have the additional feature, which is valuable in certain kinds of work, that the energy required to operate them need not be considered.

CORRECTION FOR ENERGY LOSSES IN THE INSTRUMENT ITSELF

In dealing with small currents, five amperes or less, it is often necessary to take into consideration the energy required to operate the instruments themselves. Voltmeters and the shunt circuits of wattmeters, when connected on the load side of ammeters or the series coils of wattmeters may take enough current to make a decided difference in the results if not corrected for. Some indicating wattmeters are designed to correct for their own shunt current when it passes through the series coil, but there are usually voltmeters or other wattmeters in the circuit which still have to be allowed for. If the voltage between the terminals of the voltmeter will not be affected by the voltmeter current it is sometimes practicable to open the voltmeter circuit after reading the voltmeter but before reading the other instruments. This practice of disconnecting the voltmeter is itself sometimes a source of error. As an example: suppose the voltages between the sections of a small impedance coil at a certain current are being measured while the current is passing through the whole coil. If the ammeter is read while the voltmeter is in circuit, it is obviously necessary to correct its reading for the portion of the current which passed through the voltmeter. If the voltmeter is read and then disconnected the reading observed can not be taken as that due to the current indicated immediately afterward by the ammeter because the voltage between the points where the voltmeter was connected will rise as soon as it is disconnected, due to the fact that the coil is no longer shunted by the voltmeter winding.

The accuracy of a great many tests will not be appreciably affected if the instrument losses are neglected in calculating the results, as the degree of accuracy required does not make it worth while to correct for them. It is then desirable to connect the instruments for a minimum error from that source. When the series instruments are of low resistance and the voltage under measurement is so high that the drop of voltage in the instruments is comparatively small, it is best to make all shunt connections on the line side of the series instruments, as the error due to including the drop of voltage in the series instruments is

likely to be lower than that which would result from placing the shunt instruments on the load side and thus including them with the load being measured.

If the voltage is low compared with normal working voltage of the shunt instruments, or the series instruments are loaded sufficiently to give a considerable drop of voltage between their terminals the connection of the shunt instruments to the load side may be the better plan. It does not usually require much extra time to check a reading with both methods of connection. All that is necessary is to change the lead to one side of the shunt instruments from the line to the load side of the series instruments or vice versa.

While, as stated above, there are more opportunities for inaccuracy in measuring large alternating currents than in measuring small ones, the instruments most likely to lead to error in measuring alternating-current voltages are the low-reading ones. Direct-current voltmeters and wattmeters in all ranges from 0.5 volt up are equally accurate. Voltmeters and wattmeters for use on circuits at 100 volts or more, alternating current, are generally reliable throughout a wide range of temperature and frequency. Those wound for lower voltages, particularly those for measuring e. m. f.'s in the neighborhood of ten volts, have always a relatively large temperature coefficient and the proportion of inductive to non-inductive resistance is higher. On account of this higher temperature coefficient it is important to take careful note of the temperature of low voltage alternating-current voltmeters and wattmeters. When accuracy is important or the frequency unusually high, it is also necessary to correct the readings for the inductance of the winding. If the instrument is zero-reading the inductance will be constant for all loads and can be corrected for by means of a simple factor which will be constant for any given frequency. Direct-reading instruments in which the relative position of the fixed and movable elements changes at each change in the reading, have a different inductance at each reading. Their readings can be corrected with a fair degree of accuracy by assuming that the factor suitable for the half-scale position is constant for all readings.

The correction factor is sometimes given by the instrument maker. If not, it can be found by measuring the resistance and inductance of the winding and calculating the impedance for the frequency at which it is to be used. The true volts will be higher

than the scale reading in the same proportion as the impedance is higher than the ohmic resistance. The majority of people who use portable meters do not have facilities for measuring inductance accurately, but this particular correction is so small as to be of little interest outside the laboratory, anyway. At the highest commercial frequencies the lowest reading alternating-current voltmeters require an inductance correction in the neighborhood of two per cent. A 15-volt voltmeter on a 60-cycle circuit reads within 0.1 per cent. of what it would read at the same voltage on direct current.

Mutual induction between the shunt and series coils of wattmeters is often a more important item than the self-induction of the shunt coil in causing errors in measurements at high frequencies or low power-factors. A rough check showing whether the mutual inductance in a wattmeter is excessive can be made by short-circuiting the series coil while the shunt is connected to the line at normal voltage at a frequency of 60 cycles or higher. If the movable element is freely pivoted and does not show any deflection the mutual induction between the coils is probably not high enough to cause any serious error.

PRECAUTIONS

Modern electrical instruments will stand a great deal of service under severe conditions if proper care and judgment are exercised in handling them. They will even stand a certain amount of ill treatment that would seldom be met with except through carelessness. Experience shows, nevertheless, that there are few instruments in daily service which do not occasionally meet with more or less damage. In nearly all instances where a meter is overheated, broken, or otherwise thrown out of adjustment, the cause of trouble is quite apparent as soon as the damage is done, and the person responsible finds that he knew beforehand what would happen under the conditions which caused the trouble, but had failed to notice that these conditions existed. When a man connects an ammeter in shunt across a 500-volt circuit it is seldom because he thought that the proper way, but because he thought he had a resistance, or something having the same effect, in series. To have mentioned to him a week previously that ammeters should not be connected that way would probably not have prevented the accident. It is therefore not easy to compile a useful list of connections to be avoided.

On paper, the causes which produce ninety-nine per cent. of the damage to instruments look so simple that few people who are at all familiar with electrical work would gain anything by reading them. Usually the trouble is caused by an overload of one kind or another. Wattmeters and low-reading voltmeters suffer oftener than other instruments from the kind of mistakes which are least likely to be detected in an inspection of the connections. A wattmeter operating at low voltage, say one-tenth to one-fifth of its normal voltage, will have its series coil greatly overloaded before it shows a deflection as high as half-scale. Or, if the current in the series coil is small the voltage across the shunt terminals might be raised so high that the shunt winding would burn out before the scale reading would indicate anything approaching an overload.

A voltmeter used in measuring the voltage across a highly inductive circuit, for instance, a direct-current voltmeter used in connection with an ammeter to measure the resistance of a transformer winding, may be damaged by the field discharge if the circuit is suddenly broken outside of the voltmeter connections. In a somewhat similar way, instruments connected to the armature of a machine may be injured if the field current is suddenly broken. These are examples of momentary overloads which are not likely to burn out the winding but may bend the index or strain other movable parts. When a wattmeter shunt or voltmeter is connected across part of a circuit in which the line voltage is higher than the maximum range of the instrument, it is important that the part of the circuit between the instrument terminals shall not be broken while the instrument is connected. To do so would, in most cases, practically place the total line voltage across the meter. Disconnecting a series instrument while the shunt instruments are connected to the line side of it is a common cause of such accidents.

There is no good way of protecting voltmeters against sudden great overloads; the probability of injury can be reduced by keeping them disconnected at all times when readings are not being taken. Series instruments can be protected to some extent by having switches arranged to short-circuit them, the switch being opened only when a reading is to be taken. Fuses or circuit breakers can be used to prevent the winding from being actually burned out, but they cannot prevent the mechanical shock to moving parts due to sudden overloads. With series

instruments having considerable resistance, the short-circuiting switch may not be applicable, especially if the voltage of the circuit is low. If the current were adjusted with the instrument in circuit, the short-circuiting of its resistance might cause an undesirable rise of current.

A very common practice which is detrimental to the pivot of instruments which have carrying cases separate from the meters themselves, is the habit of standing the box with its opening at the top and dropping the meter into it instead of laying the box on its side and sliding the meter in.

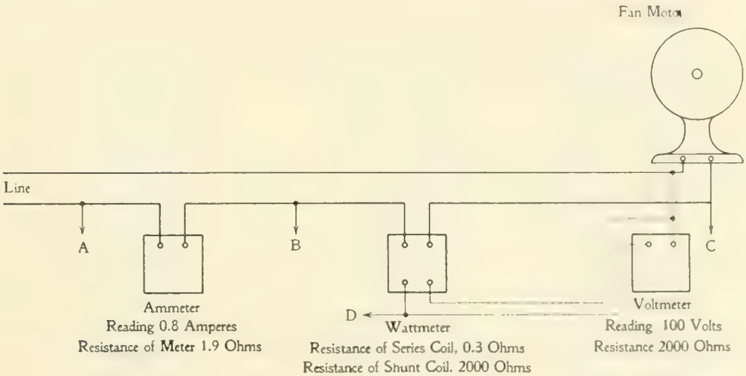
ZERO ERRORS

The question of zero errors and how to correct for them is of frequent occurrence. Sooner or later the index of nearly every meter fails to indicate zero at zero load. The exact reason is not always apparent. It may be known that the error appeared immediately after a short-circuit or after the meter was dropped to the floor, but that information would not show whether the spring had changed its shape, the index bent, some part of the movement slipped or one or more of a number of other possible disarrangements had happened. A rather common source of error at zero as well as at other readings is a fine springy piece of lint resting on a fixed part and pressing lightly against the movable part in such a way as not to cause friction, but acting as a little additional spring.

To add, algebraically, the zero error to the observed reading seldom gives exactly correct results. Sometimes it introduces a greater error than if no correction had been attempted.

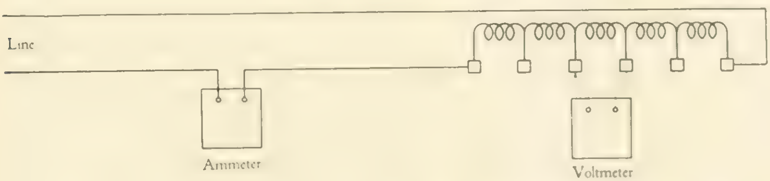
In many instances where the zero reading has changed quite appreciably, there is no difference in the calibration of the instrument at points above one-fourth scale reading. There rarely is a uniform change throughout the scale. As a general thing, it is safer to reset the zero reading or to assume that the zero error has not changed the calibration at the upper part of the scale than to attempt to correct for it. Indiscriminate resetting of the zero reading by means of the usual spring-adjustment is not to be recommended. If the error has been caused by bending the index it is better to bend it back again even though the displacement was slight. If this is not done the relative positions of the fixed and movable elements of the meter will not be the same for any given reading as they were when it was first calibrated. The

effect of this is most noticeable in those instruments which are direct-reading and do not have uniform scales. When recalibrated, the readings on the scale will be found to follow no uniform law. The reading at one point may be too high and those a short distance on either side of it too low. Such irregularities make the correction of a set of instrument readings more laborious than it would be if all readings were a certain percentage high or low.



CONNECTIONS FOR TESTING SMALL MOTOR

If instrument losses are to be corrected for, the simplest method is to connect the shunt lead *D* to *A* and allow for the drop of voltage in series coils. If the instrument losses are assumed to be negligible, connection at *A* would still be best under the conditions given on the diagram. If the current is higher or the voltage lower beyond a certain amount, connection at *B* or *C* will give a minimum error due to the instrument losses.



CONNECTIONS FOR MEASURING THE VOLTAGE BETWEEN SECTIONS OF AN IMPEDANCE COIL

The ammeter reads the vector sum of the current in the section between the voltmeter leads and the current through the voltmeter.

PROTECTIVE APPARATUS

PRESEN AMERICAN PRACTICE IN LIGHTNING ARRESTERS FOR HIGH VOLTAGE TRANSMISSION CIRCUITS

N. J. NEALL

THEORETICALLY there is no well defined dividing line between arresters suitable for low voltage and those adapted for high voltage work. Actually there are natural limitations imposed by design, cost and efficiency, and 2500 volts may be taken as a convenient point at which a marked change takes place in the type of arrester applicable for high or low voltage service.

Two factors materially affect lightning arrester design: First, the normal operating voltage. Second, the insulation of the plant as a whole. There is, in addition, an auxiliary factor, viz., the power carried on the line.

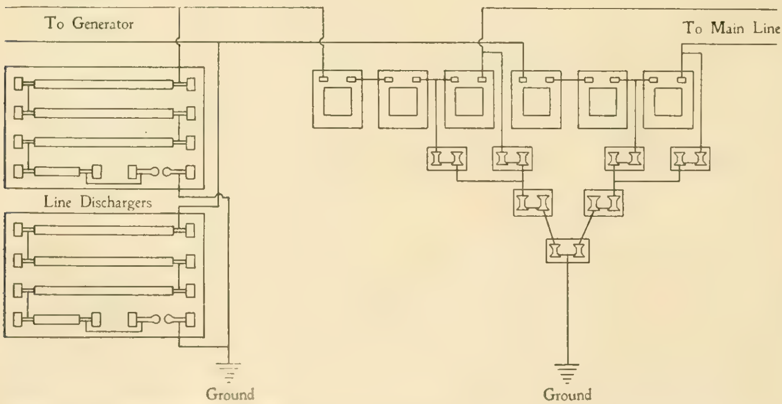


FIG. I—A NON-ARCING MULTIGAP LIGHTNING ARRESTER FOR HIGH VOLTAGE CIRCUITS. S. K. C. SYSTEM, STANLEY ELECTRIC COMPANY

The first condition limits the total air gap between the line and the ground, as the gap must be too great to permit a discharge by the normal line voltage. This gap limits also the voltage at which a lightning discharge can take place, and necessitates an insulation of the system as a whole, particularly the apparatus, which must stand a certain amount of excess voltage without injury to itself.

In low voltage systems the natural strength of insulation exerts a powerful influence in this respect, since on the whole the weakest insulation is often greatly in excess of that actually required. It is evident that any apparatus must stand certain strains since the lightning arrester must not operate below a certain defi-

nite voltage point relatively higher than the line voltage. Also the equivalent spark gap of the arrester must be smaller than that of the apparatus.*

While the high-voltage lightning arrester can be highly developed in the laboratory, yet the proof of its quality lies in its actual service. At best all present types require adjustment by actual trial. For example, the low equivalent arrester was calibrated on a 25 000 volt line direct from a large power station with various conditions of the circuit under control. It is possible empirically to deduce from this the combinations required for much higher voltage,

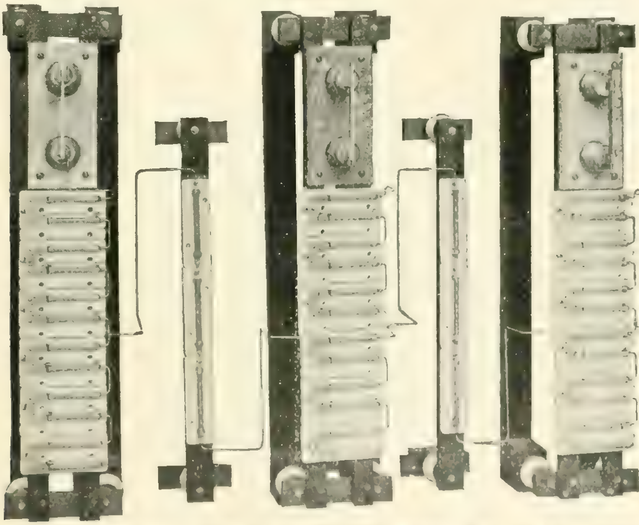


FIG. 2—12 500-VOLT LIGHTNING ARRESTER WITH MULTIPLEX CONNECTIONS—GENERAL ELECTRIC COMPANY

but the best arrangements must come from final calibration at the points in question. Long distance transmission lines are subject to direct strokes of lightning, in some instances destroying as many as twenty-five poles during one storm. While manufacturing companies have confined themselves to the design of protective apparatus solely for the protection of the station, yet the great danger to the transmission line itself is calling for a new form of protection, a transmission lightning rod, so to speak. It is clear, that the higher the voltage the longer is the transmission line likely to be, with greater exposure to the lightning. With the demand for

*See "Protective Apparatus,—The equivalent spark gap."—N. J. Neall, Vol. II., p. 224.

uninterrupted service the problem of line protection becomes serious.

In addition to a spark gap, the ideal arrester must have a very low resistance to static discharges and a high resistance to normal line voltage. These two antagonistic qualities made it difficult to find a resistance which, while within the limits of good commercial design, will operate successfully.

Modern designs mainly use two materials for this resistance, a carbon pencil and an ordinary wire resistance. The resistance to static disturbances is just as real in a carbon pencil as in a wire resistance. It is obvious that in a number of pencils in series this resistance can be so great as to materially affect the freedom of discharge of the arrester as a whole. In a wire this resistance effect can be greatly overcome by winding the wire on spools in such a way as to have the magnetic fields created by the moving charge neutralize one another. The ideal metal part is a very thin ribbon, since this offers the greatest surface to discharge and has, therefore, a minimum skin effect, but a high resistance to currents at normal frequencies. The wire resistance, therefore, allows a very free discharge. The carbon resistance, however, has a very high equivalent spark gap and an extremely low current carrying capacity. These are not bad features if coupled with a free discharge quality, but it is a well known characteristic of the carbon resistance that it heats rapidly, scales off and its resistance is abnormally increased by static discharges. This latter characteristic has been overcome to some extent by the employment of carborundum as a resistance material. Carborundum is an artificial product which will not disintegrate below approximately 4 000 degrees Fahrenheit, and can therefore stand the enormous current density at the time of a static discharge.

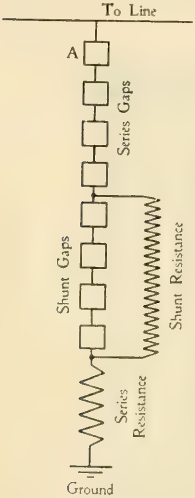


FIG 3 — ARRANGEMENT OF THE LOW EQUIVALENT LIGHTNING ARRESTER FOR 6000 VOLT CIRCUITS

Attempts have been made to use water and other liquid resistances, but pure water has a very high equivalent spark gap, while water saturated with salt has too low a resistance to limit the passing of the current on short-circuit.

The skin effect, while beneficial, is also baneful in transmission work. It has been said that the longer the transmission line, the less general trouble there is from static disturbances.

This doubtless arises from the surface resistance—the skin effect—of the transmission wires themselves which hold back the disturbances from reaching other points of the system. On the other hand it is the skin effect which makes or mars an otherwise efficient lightning arrester. Sir Oliver Lodge made the earliest investigation of this characteristic, and recent experiments conducted by the writer on the apparatus for the measurement of the equivalent spark gap show some astonishing results—ordinary wires in comparatively small lengths giving quite appreciable equivalent spark gaps. In this connection it does not take much imagination to appreciate the effect of ten to twenty-five miles of transmission wire. This very effect may cause great strains on the line insulators and be

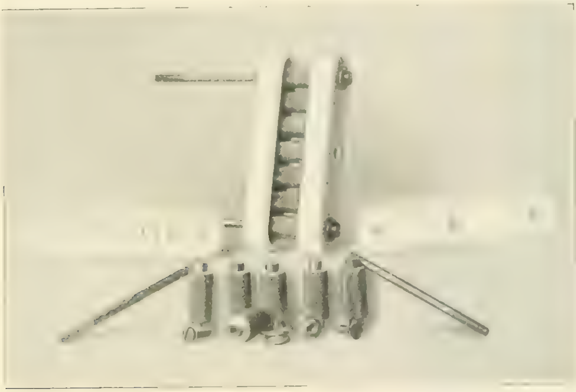


FIG. 4—TYPE R. W. GAP UNIT USED IN THE LOW EQUIVALENT LIGHTNING ARRESTER

partly the reason why insulators are jumped and broken by static disturbances on a line, since the higher the frequency the greater the skin effect, and it is generally agreed today that the frequency of lightning disturbances may be enormous.

In this country there are relatively few direct-current circuits over 2 500 volts, and these are arc lighting systems for which special types of arresters have been used.†

Aside from this, American practice tends to a universal adoption of the alternating current system, and for this in its higher voltages three lightning arrester systems are now in the field.

1. Non-arcing—Multigap—Pyramid.

†See "Protective Apparatus."—Vol. II, p, 34, 35, 36.

2. Non-arcing—Multigap—with resistance, and arranged with special connections, called multiplex.

3. Non-arcing—Multigap—with non-arcing metal, series, and shunted gaps; so-called low equivalent lightning arresters.

4. Horn—In addition to the above there has been lately introduced as protection to the line and to stations, a special form of the horn arrester heretofore used considerably abroad. This arrester is in some cases used alone at stations to protect apparatus; in other cases as an auxiliary to the standard protective apparatus, a sort of lightning rod or emergency arrester.

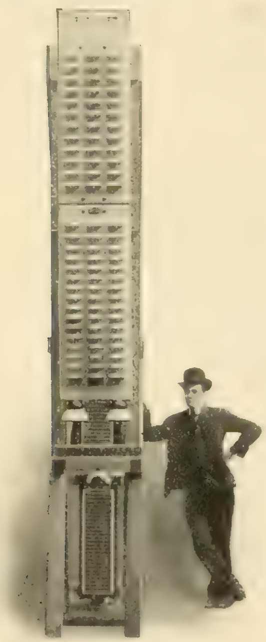


FIG. 5 — A LOW EQUIVALENT LIGHTNING ARRESTER FOR CIRCUITS EXCEEDING 18 000 VOLTS. THIS ARRESTER IS PROVIDED WITH A SPARK GAP AT THE TOP OF THE PANEL

1. NON-ARCING—MULTIGAP—S. K. C. System, Stanley Electric Company. This arrester consists of an arrangement of S. K. C. arrester units and static discharges, coupled with choke coils, as shown in Fig. 1, and operates as follows:

"In plants where both long and short gaps are installed on the same circuits, it will be noticed that static discharges of low potential and low frequency select the short gap arrester as the best path of discharge. As the discharges increase in volume and frequency the large gap arresters take the discharge, leaving only a small portion of the total to go through the short gap arresters. Therefore, neither the long nor short gap arresters alone give perfect lightning protection, as the first will not take off small discharges, while the second is unable to take all the heavy discharges. The long gap arrester will give the best protection, as the small discharges might not be able to puncture the insulation of the apparatus, while the heavier discharges would surely do some damage."

2. MULTIGAP WITH RESISTANCES AND MULTIPLEX ARRANGEMENT—General Electric Company, Fig. 2—"Due to the fact that under numerous conditions destructive high potentials exist between

phases or lines on alternating-current circuits, it has been found advisable to introduce a cross-connection at approximately the middle point of the lightning arresters when used single-phase, two-phase, or three-phase. This arrangement gives the same number of gaps from phase to phase as are used from any phase to the ground. A considerable amount of resistance is introduced into this cross-connection to prevent an excessive flow of current from phase to phase in case of one line discharging to another.

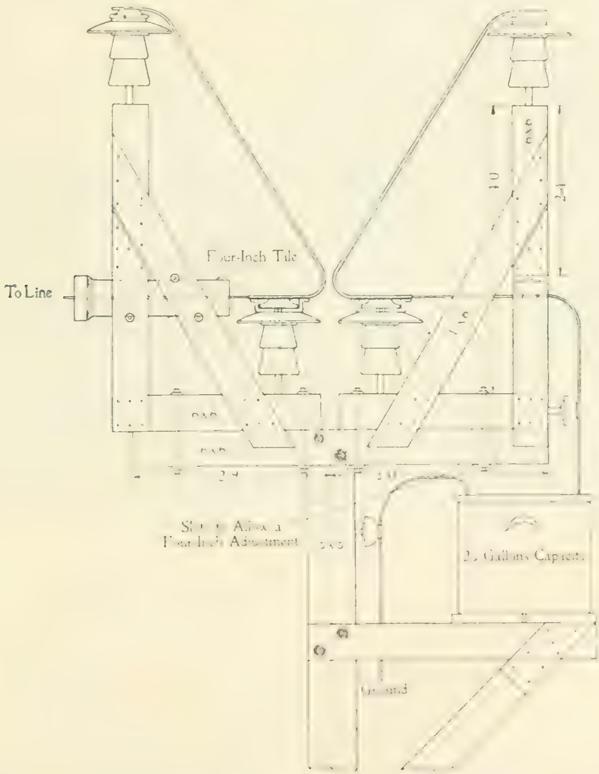


FIG. 6—CONSTRUCTION OF THE HORN TYPE ARRESTER AS USED BY THE AMERICAN RIVER ELECTRIC COMPANY

"Arresters may be connected in this wise on delta-connected circuits, and on Y-connected circuits with the neutral not grounded, but for Y-connected circuits with neutral point grounded the multiplex connection must be omitted. In protecting two-phase, four-wire circuits, two single-phase, multiplex connected arresters should be used; and when protecting two-phase, three-wire circuits, two

single-phase arresters should be used connected in between the outside legs and the common leg, no multiplex cross-connection being used between the outside legs."

3. NON-ARCING WITH RESISTANCES AND SHUNTED GAPS — Westinghouse Electric & Manufacturing Company—The low equivalent arrester consists of the following parts: A number of small air-gaps connected in series to the line, a number of which are shunted by a resistance. A non-inductive low resistance is placed in series at the lower end, Fig. 3. The various parts are connected

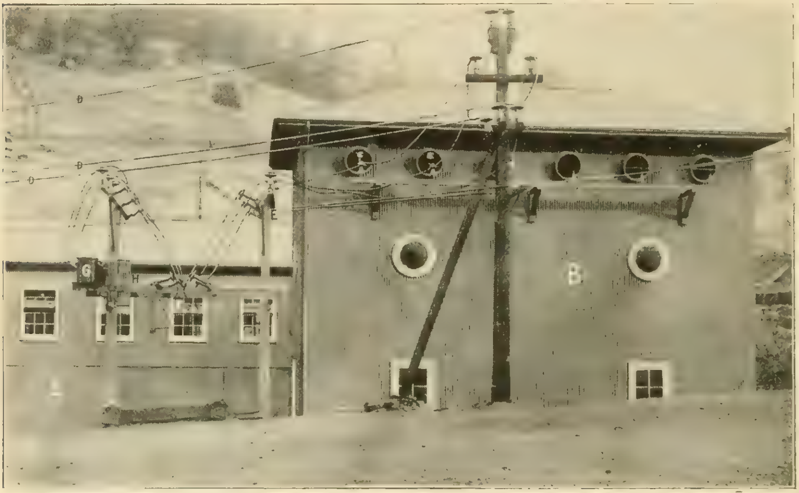


FIG 7—THE STANDARD ELECTRIC COMPANY POWER STATION AT ELECTRA, CALIFORNIA, WHERE HORN TYPE LIGHTNING ARRESTERS ARE USED ON THE 40 000 VOLT TRANSMISSION LINE

between line and ground as shown. This arrester is usually constructed single-pole.

The low equivalent arrester for a 6000 volt circuit is shown diagramatically in Fig. 3. Its operation is as follows: To cause a discharge, the potential at the line must rise until the series gaps are broken down. If the discharge is sufficiently heavy it will meet opposition in the shunt resistance and pass over the shunted gaps to earth through the series resistance. The arc which tends to follow the discharge is then withdrawn from the shunted gaps by the shunt resistance, and is suppressed by the series gaps aided by both resistances. The degree of protection secured is determined by the number of series gaps only, the shunted gaps being so proportioned that they are broken down by the potential thrown upon them when

the series gaps discharge. The number of series gaps is just sufficient to withstand the normal voltage, and to allow a proper margin for the severest condition, namely, one line grounded. The shunted gaps provide a by-pass for the lightning discharge which would otherwise meet opposition in the shunt resistance. The function of the shunt resistance is two-fold: First, to withdraw the arc from the shunted gaps after the passage of the discharge; and second, to reduce the volume of the arc so that the series gaps, too few in number to act successfully unaided, can with the assistance of the shunt gaps, suppress the arc. The small series resistance limits the initial flow of current that tends to follow the discharge and thus prevents the burning of the arrester cylinders.

The shunt and series gaps consist of one or more R. W. type gap units connected in series. The R. W. type unit, shown in Fig. 4,

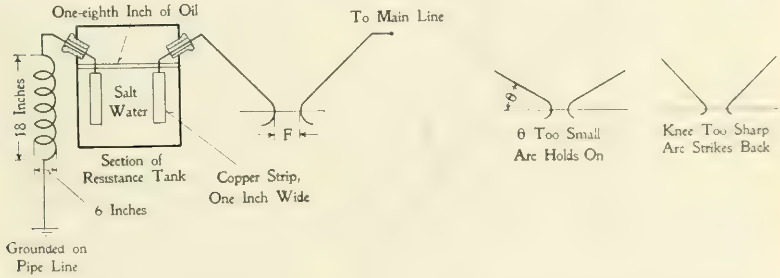


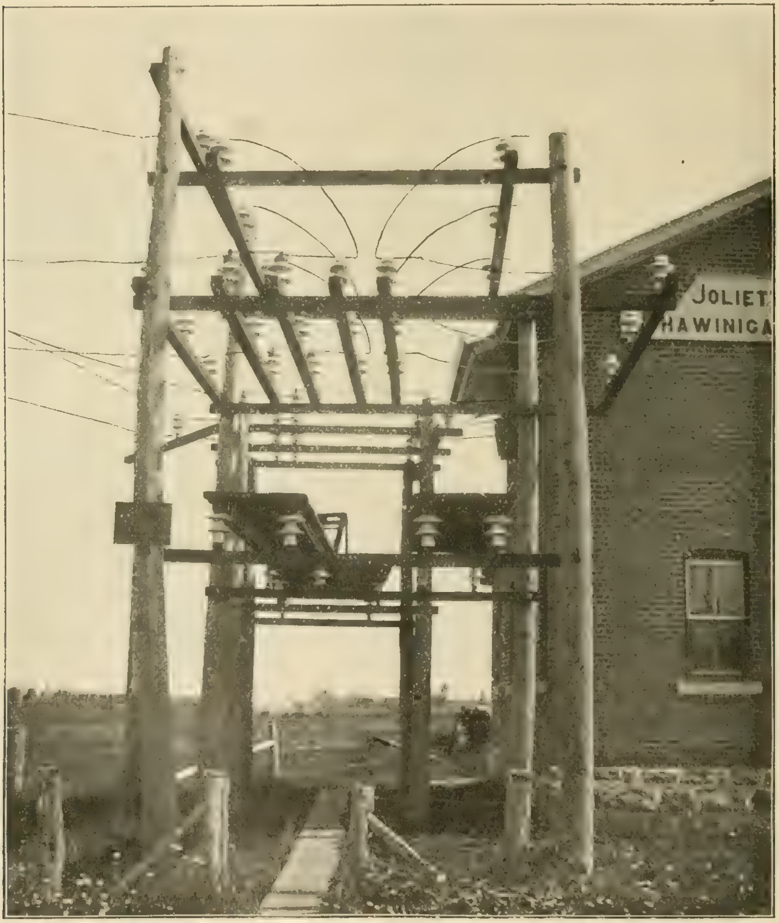
FIG 8—ARRANGEMENT OF THE PARTS OF A HORN TYPE LIGHTNING ARRESTER. THE TWO SMALL DIAGRAMS TO THE RIGHT SHOW FAULTY CONSTRUCTION OF THE HORNS—N. A. ECKERT

consists of seven small cylinders, forming six gaps, the cylinders being held in position by porcelain pieces.

On arresters for circuits exceeding 18 000 volts, in addition to the usual series of R. W. type units, an adjustable auxiliary spark gap is used, Fig. 5. This gap is placed in series with those arrester units next to the line. It allows a slight amount of adjustment in connection with the series gaps. In this auxiliary gap one turn of the adjustable head changes the gap by 1/32 of an inch.

4. THE HORN LIGHTNING ARRESTER—The horn lightning arrester was first brought out in Germany by Oelschlaeger, its inventor, for the Allgemeine Electricitaets Gesellschaft, and bases its operation on the fact that the short-circuit arc once started at the narrow gap between the horns, Fig. 6, the heat of the arc will cause it to travel upward along the horns and break by reason of its attenuation. Of course a certain

amount of time is required to do this—something like two seconds —and on large plants the resulting short-circuits would not only be objectionable but in many cases where synchronous apparatus could fall out of step, it would be prohibitive. At the International Elec-

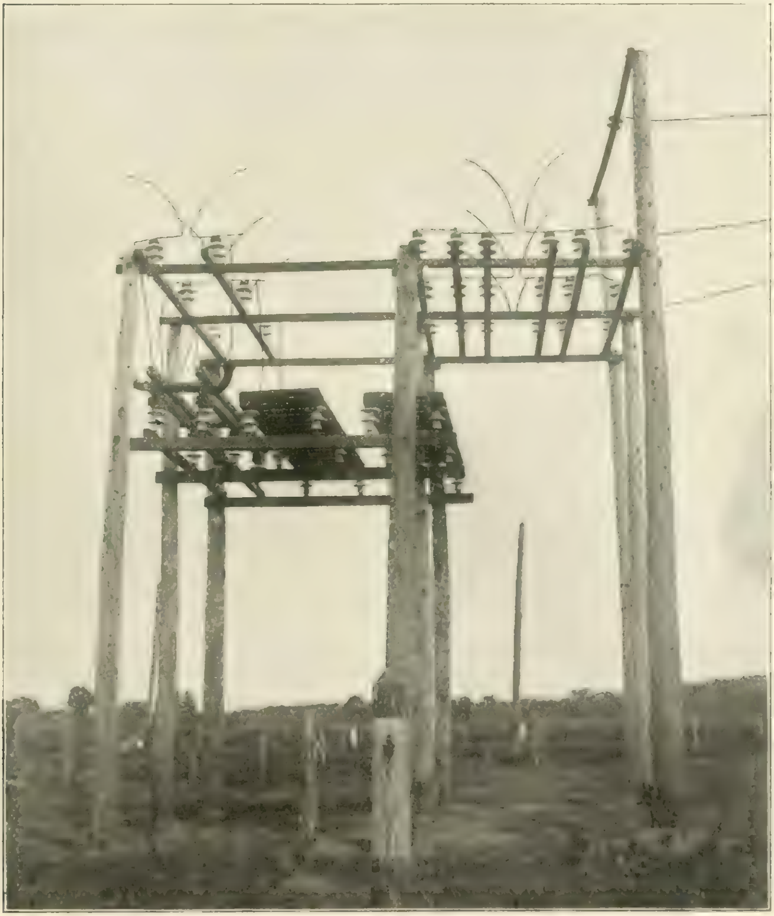


HORN TYPE LIGHTNING ARRESTERS AT THE JOLIETTE SUB STATION OF THE SHAWINIGAN WATER AND POWER COMPANY. NO RESISTANCE IS USED WITH THIS INSTALLATION. A FUSE IS PLACED IN THE LINE GROUNDING ONE OF THE HORNS

trical Congress at St. Louis, Mr. F. G. Baum of the San Francisco Gas & Electric Corporation, stated that on their system (formerly the Bay Counties and Standard Electric Companies, now working in parallel) this type of arrester had been known to operate frequently

without affecting the service, and no effect was felt at distant points. At another plant of the company a horn arrester has been known to operate without blowing the fuse in series with it.

In the following will be found a description of three typical and



HORN TYPE LIGHTNING ARRESTERS USED BY THE SHAWINIGAN WATER AND POWER COMPANY AT JOLIETTE, P. Q. A RESISTANCE IS USED WITH THE GAPS IN PARALLEL

important high tension installations using these arresters. First, the Standard Electric Company, the pioneer; second, the American River Electric Company, California; and third, the Shawinigan Water & Power Company, Montreal.

THE STANDARD ELECTRIC COMPANY.

"The three legs of the main line pass from the transformer and high tension switch room *A*, Fig. 7, directly through the building *B*, emerging at *ccc*, and thence to the transmission line *DDD*. The horn arrester, or the "Dutchman" as it is generally called, is connected to the line at *ccc*. As the picture shows, the apparatus is very simple, in fact its cheapness is strongly in its favor. As used at Electra, it consists of an air gap at *F* in series with a water resistance and an iron wire resistance and a choke coil *H* from which it is connected to the ground.

"The knee shaped spark terminals are formed of about No. 0000 copper wire, supported on the regular line insulator; the water resistance consists of copper strips immersed in a salt solution contained in the jars *G* which are of about 15 gallons capacity each. The salt water is covered with about 1/8 inch of oil to prevent evaporation. The resistance choke coils consist of about 18 turns of iron wire wound on a 6-inch cylinder, the cylinder being removed before mounting. The arrangement is shown diagramatically in Fig. 8.

"The gap *F* is adjustable. While operating at 40 000 volts the distance was 3 to 3¼ inches. The protector as described was installed by Mr. A. C. Bunker in 1902, while he was in charge, and the same device is now in use on the lines of the California Gas & Electric Corporation which now owns and operates the Standard plant. Mr. Bunker lays great stress on the curve of the knees, and the form shown in Fig. 7 was adopted after considerable experimenting. If the wires separate too abruptly above the gap the arc will not follow up and extinguish itself; if the crook in the knee is too sharp the arc will either hold on or rise and extinguish itself and immediately strike back again at *F*.

"Further the curve of the knee depended on the value of the line constants at the point protected, for a curve that gave the best satisfaction at one point on the line was not the best at another.

"In California, the lightning storms lack the severity and frequency of those further east, but as an instance of the value of the protection afforded against line surges, I may mention some switching experiments carried on at Mission San Jose, 100 miles from Electra. These experiments or tests were for the purpose of establishing the value of a certain type of switch, and consisted of closing and opening the switch with 10 000-kw. at 40 000 volts be-

hind it. As a rise in the line voltage was expected the gap *F* at the power house was increased to 4¼ inches. About the fourth time the switch was opened the arrester discharged and the arc extinguished itself. The test was repeated and the arrester again discharged, but so violently as to blow all the water out of the resistance jars. No damage was sustained by any of the transformers or instruments.

"I do not know of any transformer being broken down by lightning or similar disturbances where protected by this apparatus.

"The chief objection offered to it is the length of time the arc or short holds on after the discharge to ground. This may be as long as a second or a second and a half. However, the arrester does not discharge very frequently."—Letter from N. A. Eckert.

THE AMERICAN RIVER ELECTRIC COMPANY

"The horns are of galvanized iron gas pipe, and for our voltage of about 40 000, we separate them about 2¼ inches. A jar of water, covered with oil, is used for a resistance in the ground wire. The oil of course is simply to reduce the evaporation. We have used both pure water, and water with salt added, but find the pure water is more satisfactory. These arresters have been in operation for about eighteen months, and have gone through several lightning storms. Several of the employees have witnessed their action during the storms.

"In one instance they discharged several times in succession, the arc traveling about half way up the horn before breaking.

"Every discharge had the same effect as a temporary short-circuit, causing the voltmeters to swing entirely across the scale, and the lights to dip to perhaps half candle power.

"We have had no trouble from these arresters, no damage done by lightning, and consider the arrester as satisfactory for high voltages as any now in use.—Letter from B. C. Condit, Gen'l Sup't.

THE SHAWINIGAN WATER & POWER COMPANY

"Replying to your of July 17th, referring to the horn type lightning arrester, I am sending you herewith two photographs. In brief I can only state that we have found these horn arresters very satisfactory for heavy discharges, the main trouble with them, however, being that they create considerable disturbance on the system when they discharge.—Letter from Julian C. Smith, Sup't.

HOW TO START ROTARY CONVERTERS*

ARTHUR WAGNER

Case IV.

Two three-phase rotary converters each operating from alternating to two-wire direct current, the direct-current sides to operate in parallel. Each machine is started by its own starting motor and synchronizing rheostat.

The first converter *A* is started as follows:

1. Open all the circuit breakers and switches; cut in all the resistance of the field rheostat.

2. Close the high tension circuit breakers. This energizes the circuits down to switches (1) and (2).

3. Put in the two three-point synchronizing plugs and also the two-point plug *a*, which connects the converter shunt transformer to converter *A;* put the direct-current voltmeter plug in its receptacle, so that the voltmeter will indicate the direct-current voltage as the converter comes up to speed; bring the alternating switch (1_a) to within about one inch of closing so that it may be thrown in quickly at the proper time.

4. Close the starting motor switch (2_a), and before the converter gets up to speed close the synchronizing rheostat switch (3_a) in order that the rotary converter will approach synchronism gradually. It would be an unnecessary load on the starting motor to start with the synchronizing rheostat in.

5. Adjust the field rheostat to build up the direct-current voltage to approximately the bus voltage. See that the direct-current voltage has built up in the right direction.

6. When the synchroscope points vertically upwards (simultaneously with the synchronizing lamps becoming dark) close the alternating-current switch (1_a).

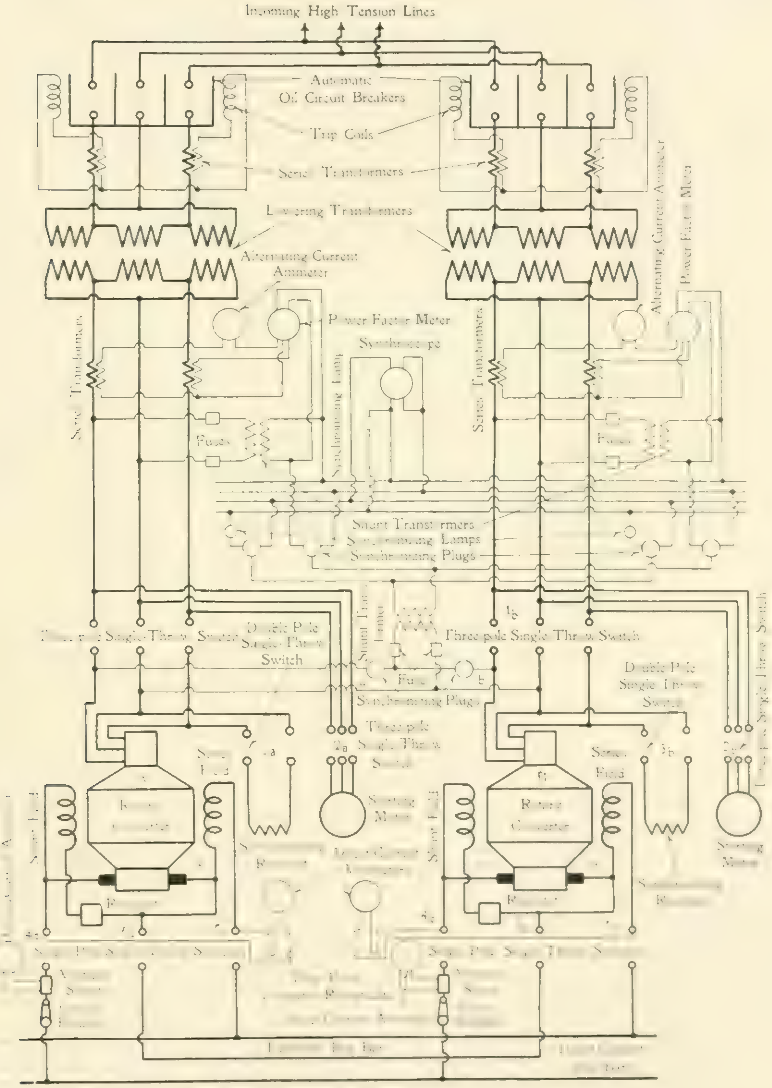
7. Open the synchronizing rheostat switch and the starting motor switch and remove the synchronizing plugs.

8. Adjust the field rheostat until the power-factor meter indicates a maximum power-factor, when the alternating-current ammeters will indicate the minimum current.

9. Close the direct-current circuit breaker and the negative and positive switches, (4_a) and (5_a) and also the equalizer switch (6_a).

The second converter *B* is started and synchronized in a similar

*Mr. Wagner's series consists of eight cases each accompanied by a full page diagram of connections.



CASE IV.

CONNECTIONS FOR SYNCHRONIZING TWO THREE PHASE ROTARY CONVERTERS OPERATING FROM ALTERNATING TO TWO-WIRE DIRECT CURRENT. THE MACHINES ARE STARTED WITH SEPARATE STARTING MOTOR AND SYNCHRONIZING RHEOSTATS, THE DIRECT CURRENT SIDES TO OPERATE IN PARALLEL.

manner, of course using the two three-point and the two-point (b) synchronizing plugs on its own panel.

The direct-current sides are paralleled as follows:

1. See that both direct-current voltmeters indicate equal voltages: the voltage can be varied slightly by shifting the direct-current brushes.

2. Close the positive switch (5_b) and the circuit breaker; then when the load on the first machine approaches a minimum, as indicated by its ammeter, throw in the negative and equalizer switches (4_b) and (6_b) on the second machine.

If the first machine possesses a strong series field and is heavily loaded, the sudden rush of current due to the dividing of the load may reverse the polarity of the first machine. To prevent this, the series field of both machines may be short-circuited while paralleling.

Note—By the use of the synchronizing plugs *a* and *b* only one instead of two converter shunt transformers is necessary.

Note—The method of starting each converter is practically the same as Case I.

Case V.*

One three-phase rotary converter operating from alternating to three-wire direct current. The machine is started by a separate starting motor and a synchronizing rheostat.

1. Open all the circuit breakers and switches; cut in all the resistance of the field rheostat.

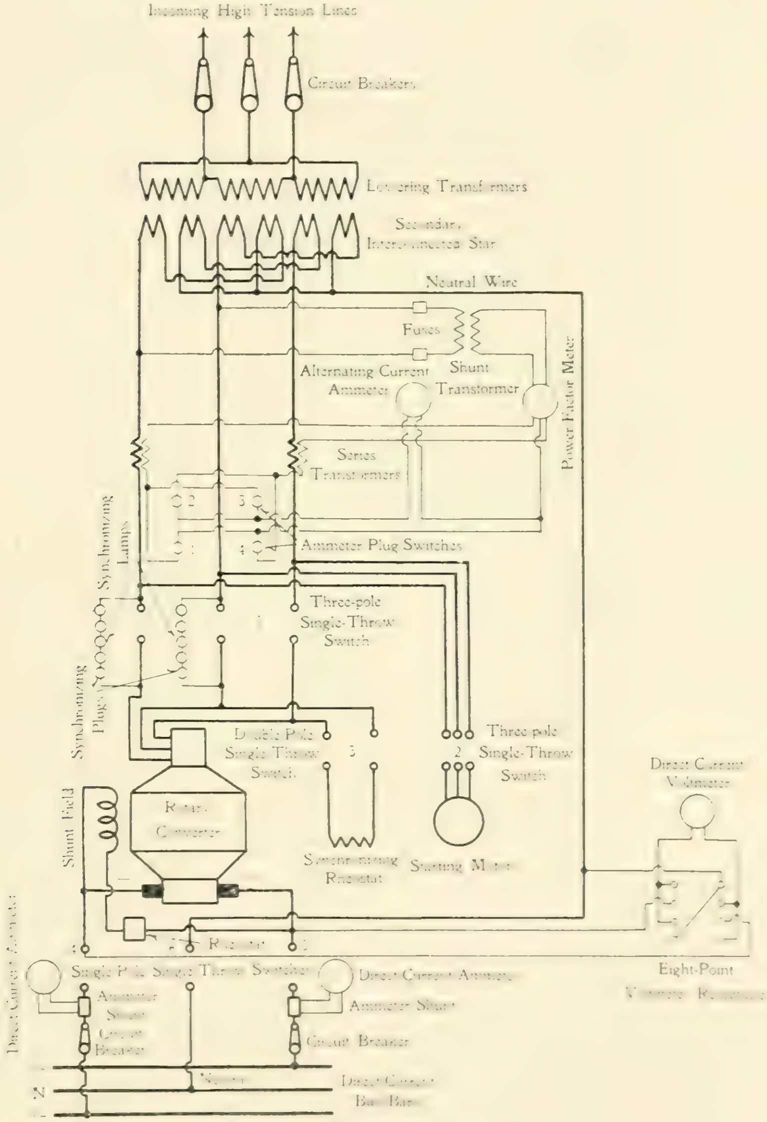
2. Close the high tension circuit breakers. This energizes the circuits down to switches (1) and (2).

3. Put in the synchronizing plugs, which should cause the synchronizing lamps to burn dimly; put the direct-current voltmeter plug in its receptacle, so that the voltmeter will indicate the direct-current voltage as the converter comes up to speed; bring the alternating-current switch (1) within about one inch of closing so that it may be thrown in quickly at the proper time.

4. Close the starting motor switch (2), and before the converter gets up to speed close the synchronizing rheostat switch (3) in order that the rotary converter will approach synchronism gradually. It would be an unnecessary load on the starting motor to start with the synchronizing rheostat in.

5. Adjust the field rheostat to build up the direct-current volt-

*Case V is practically the same as Case I.



CASE V.

CONNECTIONS FOR SYNCHRONIZING ONE THREE-PHASE ROTARY CONVERTER OPERATING FROM ALTERNATING TO THREE-WIRE DIRECT CURRENT. THE MACHINE IS STARTED WITH A SEPARATE STARTING MOTOR AND A SYNCHRONIZING RHEOSTAT.

age to approximately the bus voltage. See that the direct-current voltage has built up in the right direction.

6. As the converter approaches synchronism the pulsations of

the lamps grow slower; wait until they are slow and regular and then as the lamps are approaching darkness close the alternating-current switch (1). It is better that the switch be closed just before the lamps become dark rather than later, when the converter is receding from synchronism.

7. Open the synchronizing rheostat switch and the starting motor switch and remove the synchronizing plugs.

8. Adjust the field rheostat until the power-factor meter indicates a maximum power-factor, when the alternating-current ammeters will indicate the minimum current. By the use of the four two-point plug-switches 1, 2, 3, 4, it is possible to read the current in any one of the three lines with only one alternating-current ammeter. To read the current in the left hand line open plugs 1 and 2, thus compelling the current in the secondary of the series transformer in the left hand line to pass through the alternating-current ammeter, by means of the plug 3; the other series transformer is short-circuited through the power-factor meter by means of plug 4. To read the current in the right hand line open plugs 3 and 4, with 1 and 2 remaining closed. By opening 1 and 4, leaving 2 and 3 closed, the currents in the two outside lines combine and pass through the ammeter, this current being equal to that in the middle line.† If the plugs be left in such a position as to open-circuit the secondary of either series transformer, the latter would not only heat up to a destructive temperature, but also a dangerous voltage would be induced in the secondary coils.‡

9. Close the direct-current circuit breakers and the negative (4), positive (5) and neutral wire (6) switches, thus connecting the converter to the direct-current bus-bars.

The secondaries of the lowering transformers are arranged in inter-connected star, from which the neutral or third wire is obtained. The direct-current carried in this wire divides equally in both directions through the transformers, and therefore has no effect on the magnetization of the iron. The eight-point voltmeter receptacle is so connected that by placing the four-point voltmeter plug in the top position the voltmeter indicates the potential from plus to *N;* in the middle position, the potential from plus to minus; in the bottom position, from *N* to minus. In each position of the plug the left hand terminal is positive with respect to the right hand

†See *The Electric Club Journal,* Vol. I, p. 247.

‡See "Operation of Series Transformers," *The Electric Club Journal,* Vol. I, p. 451.

terminal, a condition necessary in order that the voltmeter read in the same direction for all three positions of the plug.

CASE VI.*

One two-phase rotary converter operating from alternating to three-wire direct-current. The machine is started by a separate starting motor and a synchronizing rheostat.

1. Open all the circuit breakers and switches; cut in all the resistance of the field rheostat.

2. Close the high tension circuit breakers. This energizes the circuits down to switches (1) and (2).

3. Put in the synchronizing plugs, which should cause the synchronizing lamps to burn dimly; put the direct-current voltmeter plug in its receptacle, so that the voltmeter will indicate the direct-current voltage as the converter comes up to speed; bring the alternating-current switch (1) within about one inch of closing so that it may be thrown in quickly at the proper time.

4. Close the starting motor switch (2), and before the converter gets up to speed close the synchronizing rheostat switch (3) in order that the rotary converter will approach synchronism gradually. It would be an unnecessary load on the starting motor to start with the synchronizing rheostat in.

5. Adjust the field rheostat to build up the direct-current voltage to approximately the bus voltage. See that the direct-current voltage has built up in the right direction.

6. When the synchroscope points vertically upwards (simultaneously with the lamps becoming dark) close the alternating current switch (1).

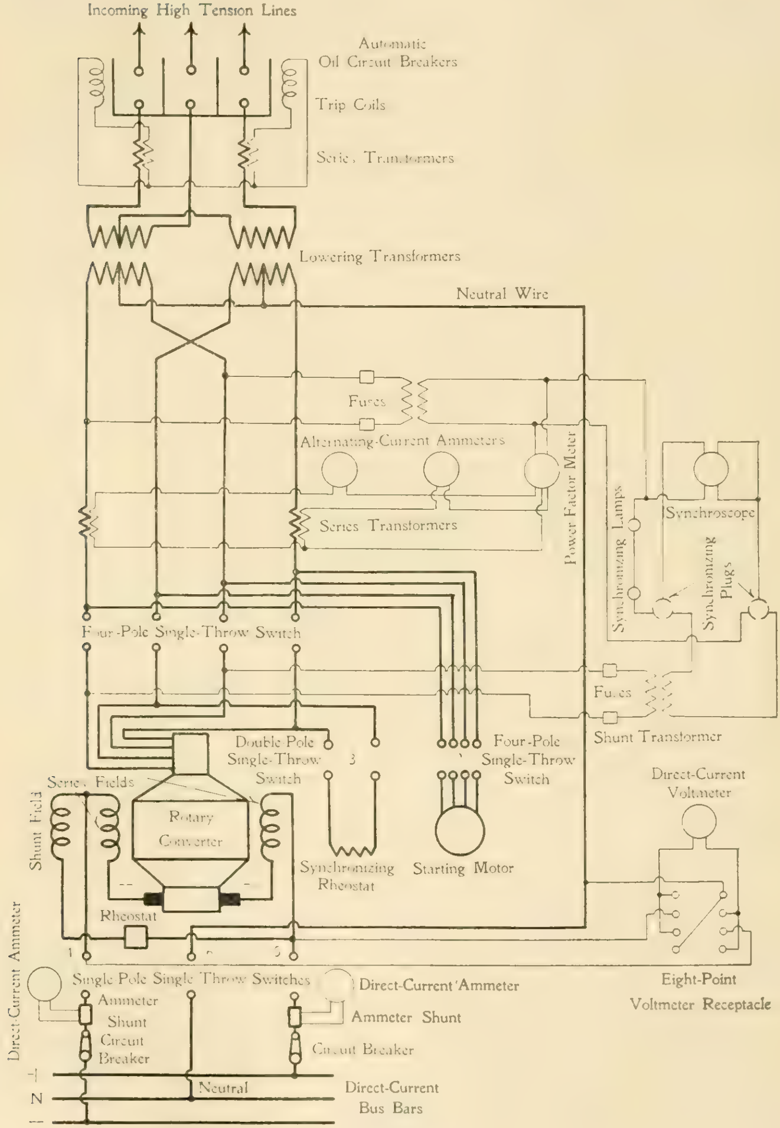
7. Open the synchronizing rheostat switch and the starting motor switch and remove the synchronizing plugs.

8. Adjust the field rheostat until the power-factor meter indicates a maximum power-factor, when the alternating-current ammeters will indicate the minimum current.

9. Close the direct-current circuit breaker and the negative (4), positive (5) and neutral wire (6) switches, thus connecting the converter to the direct-current bus-bars.

In order to maintain the balance of electromotive force independent of which side carries the load, two series field windings are necessary, one leading from each of the terminals of the machine. The series winding on the positive poles is connected to the positive terminal, and the series winding on the negative poles to the negative terminal. A shunt wound converter, such as referred to

*Case VI is practically the same as Case I.



CASE VI.

CONNECTIONS FOR SYNCHRONIZING ONE TWO-PHASE ROTARY CONVERTER, OPERATING FROM ALTERNATING TO THREE-WIRE DIRECT CURRENT. THE MACHINE IS STARTED BY A SEPARATE STARTING MOTOR AND A SYNCHRONIZING RHEOSTAT

in Case V is acceptable where the load is fairly constant and balanced, but an ordinary compound wound converter would be unsuitable for practical operation.

POLYPHASE MOTORS ON SINGLE-PHASE CIRCUITS

G. H. GARCELON

OCCASIONALLY it is desirable to operate a polyphase induction motor on a single-phase circuit. Its characteristics, however, will not be as good as before, and some special device will have to be employed to make it self-starting.

The definite relations given below are applicable only to motors having cage-wound secondaries. Motors with coil-wound secondaries can also be operated single-phase but their performance will depend to a large extent upon the secondary resistance and in general will not be so good as that of motors with cage-wound secondaries.

A motor operating in this manner will, with the same slip and temperature rise, carry approximately 70 per cent. of its normal

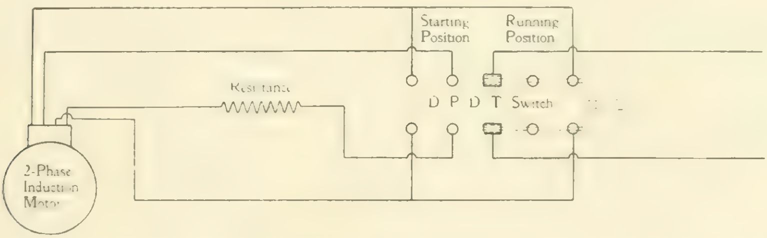


FIG. [illegible]—CONNECTIONS FOR OPERATING A TWO-PHASE INDUCTION MOTOR ON A SINGLE-PHASE CIRCUIT

polyphase load. The pull out or maximum running torque, will be decreased one-half or one third, depending upon the slip; the motor having the smaller slip giving the greater pull-out. The efficiency and power-factor will in general be highest at 70 per cent. of the normal polyphase load, but will be from six to twelve per cent. lower than originally.

Operating as a single-phase motor the polyphase motor will not develop any starting torque. It is not necessary, however, to bring the motor up to more than one-fifth normal speed in order to make it pick up when the load is very light. The motor may therefore be started by a vigorous pull on the belt.

If it is desirable to make the motor self-starting, it can be accomplished by using resistance, inductance, or capacity in one or more of its phases. In this manner the current in the different circuits is thrown out of phase, or split, which will give a weak rotat-

ing field sufficient to produce a small torque. There will be a large loss in the resistance or whatever device is used to split the phase. Therefore it is generally cut out after the motor is up to speed.

Fig. 1 shows a method of connecting a two-phase motor and resistance through a double-throw switch. The curves, Fig. 2, show the results of a test on a two-phase motor operated in this way. These show that the starting-torque depends on the value of the resistance in series with the starting phase. It will also be noted that the torque increases as the resistance is decreased until a maximum is reached, when, if the resistance is still further decreased, the torque falls off very rapidly. This maximum point is explained as follows: The larger the value of the resistance, the greater the phase difference in the two circuits and the more nearly is the condition of a two-phase circuit approached. On the other hand, the larger the value of the resistance, the smaller the current in that winding. The torque depends both on the magnitude of the currents and their phase relation and the maximum torque occurs when the resultant effect of the two is a maximum.

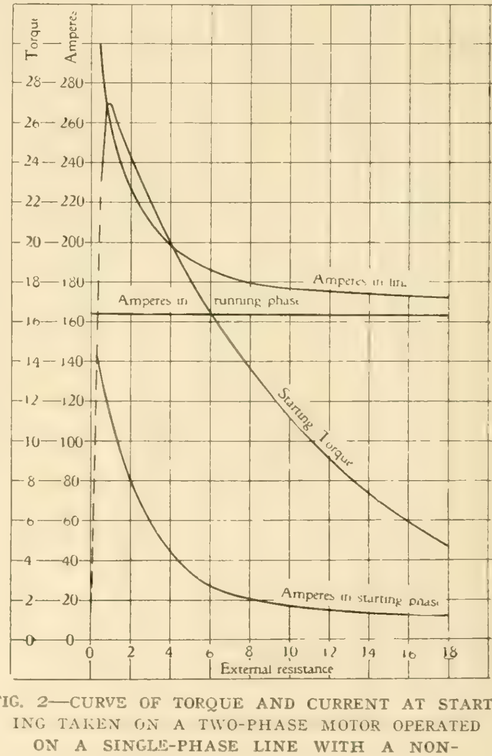


FIG. 2—CURVE OF TORQUE AND CURRENT AT STARTING TAKEN ON A TWO-PHASE MOTOR OPERATED ON A SINGLE-PHASE LINE WITH A NON-INDUCTIVE RESISTANCE IN ONE-PHASE

Fig. 3 shows the phase relation and the relative values of the current in each circuit for two different values of the external resistance. *OE* represents the line voltage. This consists of two components at right angles, the ohmic drop and the inductive drop. Since the same voltage is applied to each circuit, *OE* will be the

resultant of the ohmic and inductive drops of each. Ir and Ix are the ohmic and inductive drops respectively in the running circuit, the inductive element being much the larger. The current, in phase with Ir, is represented by I and lags behind E by an angle φ. When there are four ohms in series with the starting phase the current in that circuit is I_1 and the drops are I_1r_1 and I_1x_1. The current in the starting phase is here ahead of that in the running phase by an angle φ_1. This gives a good split but the current, I_1, is small and therefore the torque is small. The total current drawn from the line is

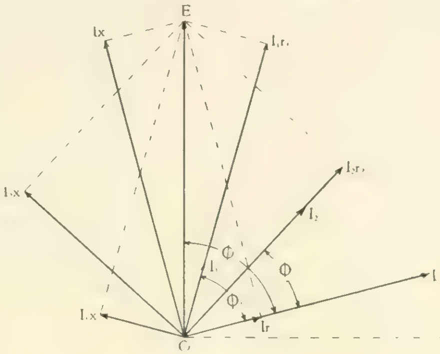


FIG. 3

the resultant of OI and OI_1. With one ohm in series, which gives approximately the maximum torque, the current is I_2, the drops are I_2r_2 and I_2x_2, and the phase difference is φ_2. The line current will be the resultant of I and I_2. For a given motor the value of the resistance to be used is best determined by a simple test. Place a non-inductive resistance (water rheostat) in series with one phase and adjust it until a desirable torque is obtained. Then measure the volts across the rheostat and the current in the

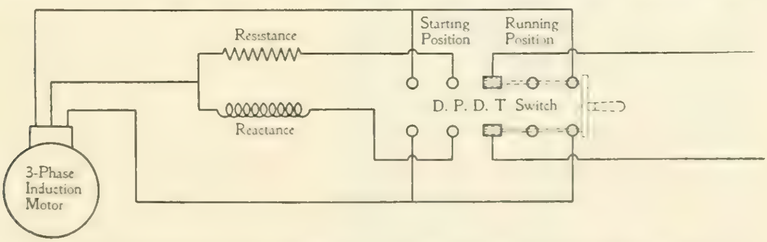


FIG. 4—CONNECTIONS FOR OPERATING A THREE-PHASE INDUCTION MOTOR ON A SINGLE-PHASE CIRCUIT

starting circuit. The volts divided by amperes will give the ohms required.

Fig. 4 shows a three-phase motor connected for operation on a single-phase circuit. In this case both inductance and resistance are used for starting. The current in the different circuits is split as before, but here there are three currents each of which is out

of phase with the other two. This motor could be started with either the resistance or the inductance alone. Resistance will give better results than inductance because the motor winding itself is almost entirely inductive, as can be seen from the curves of Fig. 2, and therefore the current in the starting phase cannot be made to lag very far behind that in the running phase.

Condensers are sometimes used. They are, however, expensive and none too reliable. A condenser will of course give a much larger phase difference than resistance, but in order to be of sufficient capacity to carry an appreciable current it must be quite bulky. If allowed to remain in circuit while the motor is running it will raise the efficiency some and the power-factor very materially.

In general the most satisfactory method of splitting the phase will be found to lie in the use of a simple non-inductive resistance, which may readily be improvised.

SINGLE-PHASE SYNCHRONOUS TRANSMISSION*

Abstract of an Address by

P. N. NUNN

Chief Engineer of the Telluride Power Company

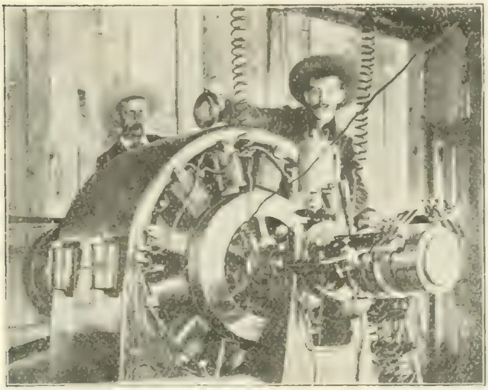
THE ORIGINAL POWER STATION—AMES, COLORADO

THE first high voltage alternating-current power transmission in this country was installed at Telluride, Colorado, in 1890. Mr. Nunn was the engineer and his address recounted the early history of the Telluride installation from three points of view, the locality, the apparatus, and the young men engaged in construction work. In substance Mr. Nunn spoke as follows:

Before the generators had been placed on their foundations, the heavy winter snows set in. Most of the construction work had been completed excepting the power house, all of the material for which was not on the ground. In the emergency, the rough wooden shed, shown in the illustration, was put up in two days time and did service as a power house till late in the following spring.

*A short account of an illustrated lecture before The Electric Club, April 26, 1905.

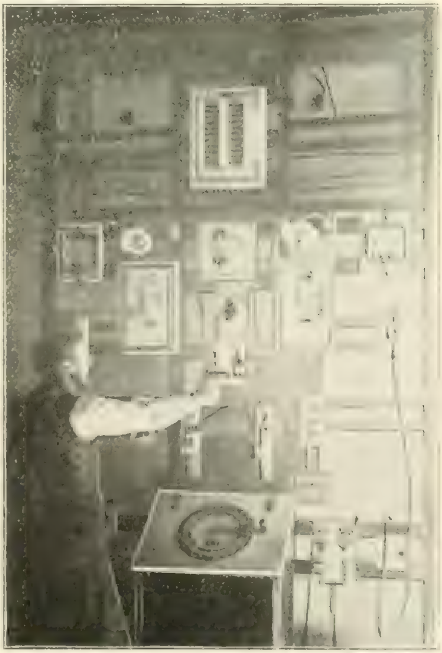
The system was single-phase throughout. The first installation consisted of one 100 hp synchronous motor and one generator. The two machines were identical, except in some of their windings. The armatures were wound for 3 000 volts and the current was transmitted at this voltage without the intervention of transformers.



THE FIRST 3 000-VOLT SINGLE-PHASE GENERATOR—AMES

Later a larger generator was installed and also a number of single-phase synchronous motors ranging from 50 to 250 hp. Some of the motors were made self-starting by means of commutators mounted on one end of their shafts. They started as series motors and suggest the modern single-phase railway motors.

In the original installation the synchronous motor was brought up to speed by a single-phase Tesla induction motor, the initial start of which was given by hand. When the starting motor came up to speed, it was connected by a friction clutch to the armature of the synchronous motor which was brought up to the required speed for synchronizing.



SYNCHRONIZING ONE OF THE SINGLE-PHASE SYNCHRONOUS MACHINES — BEAR CREEK. THIS SWITCHBOARD WAS CONSTRUCTED ALMOST ENTIRELY OF WOOD

The synchronous motor

was self-exciting. A low voltage winding on the armature was connected with a two-part commutator by which the current was rectified for exciting the field.

In one case an exciter was installed with the motor. At first it was driven from the shaft of the motor. This proved unsatisfactory as the exciting current varied when the motor speed was disturbed and the system was unstable. The motor pumped badly and would fall out of step. This was remedied by installing for a time a steam engine to drive the exciter.

One customer was very fortunately situated near a small water

A HILLSIDE SUPPORT IN THE EDGE OF A SNOWSLIDE

fall which was harnessed to the exciter and everything worked beautifully till the stream went dry, when for a short time a steam pump was used to supply water to run the turbine that drove the exciter for the synchronous motor. This lasted but a few weeks.

It is interesting to note that one customer had a 50 hp single-phase motor that ran continuously for one year and nine months, which is a record well worthy of modern apparatus.

The single-phase system was soon replaced by polyphase apparatus, yet the original layout was the first to establish the success of the long distance transmission of power in the Rocky Mountains and to prove the practicability of high voltages for power transmission.

The water supply for the Ames power house is ideal. Near the summit of the mountains there is a lake occupying the crater of an extinct volcano. It was decided to drive a tunnel into the side of the mountain tapping the lake. Almost every geographic and climatic condition was against this task and also it was difficult to find men willing to go to the tops of the mountains and work under the most severe conditions of ice and snow and cold.

A SPECIAL BENT IN WINTER—CAMP BIRD DIVIDE

In connection with this work Mr. Nunn early appreciated the need of a systematic training for the young men in his employ. With this in mind he organized what might be termed an apprenticeship course which was to the fellows in the field of construction what The Electric Club is to the apprentices in the works.

In conclusion, Mr. Nunn said, "The student in the works is very apt to become passive, and accustomed to following directions. For the most part, his work is planned for him and it is seldom necessary for him to assume the responsibility of decision.

"In the field of construction he must not only do the work, but must find it, and find the best method of doing it; and all this he must frequently do alone. He must take the initiative and should possess sufficient self-confidence to take a reasonable chance on anything even though he may sometimes do the wrong thing."

THE CITY OF TELLURIDE, COLORADO

MODERN PRACTICE IN SWITCHBOARD DESIGN

PART VII—HIGH TENSION SWITCHBOARDS, HAND CONTROLLED—Continued

By H. W. PECK

PLANTS of small output and high voltage may be practically as simple in their switchboard equipment as those of low voltage. Oil switches replace the knife-blade type and transformers are interposed between the main circuits and the meters.

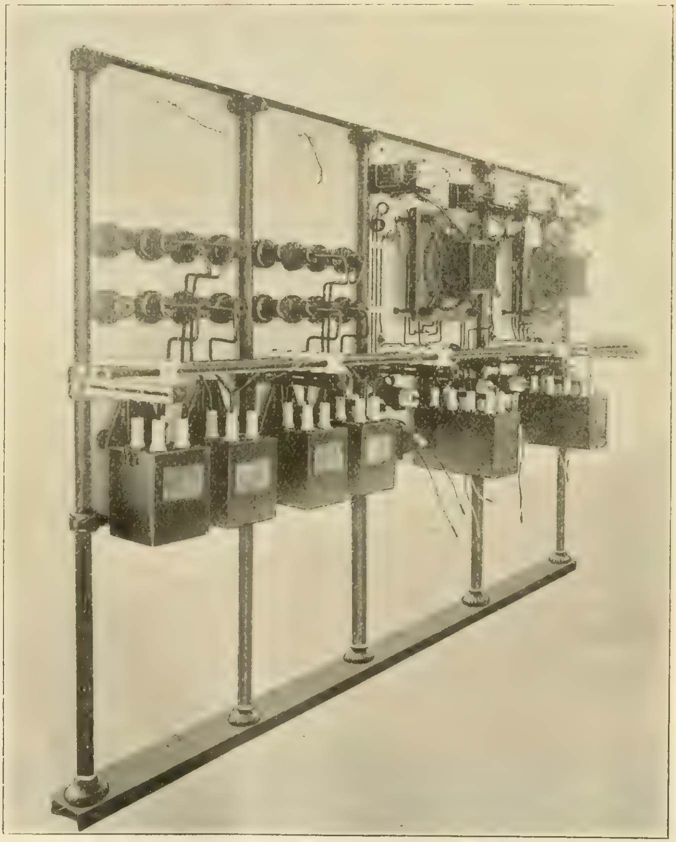


FIG. 23—REAR VIEW OF A SWITCHBOARD FOR SMALL OUTPUT AND HIGH VOLTAGE

The arrangement of apparatus will be the same as that shown in Fig. 19 (Vol. II., p. 312), a typical rear view being shown in Fig. 23. The bus-bars and wiring are usually made of insulated wire carefully spaced and supported by porcelain insulators. Sufficient

space must be left below the oil switches to permit the removal of the oil tanks for inspection of the contacts and of the oil.

A good illustration of the front view of a large board for high tension service is given in Fig. 24. This board is constructed of standard size panels 24 inches wide and 90 inches high. When it is possible, the field ammeters on the generator panels are located immediately below the other meters on a line with the meters on the first two and the further panels. This arrangement gives the board a more symmetrical and pleasing appearance. However, in this case it was desirable to locate the field rheostat face plates on frame work directly back of the panels, and in order to leave a free passage back of the board, the hand wheels and shafts were raised as

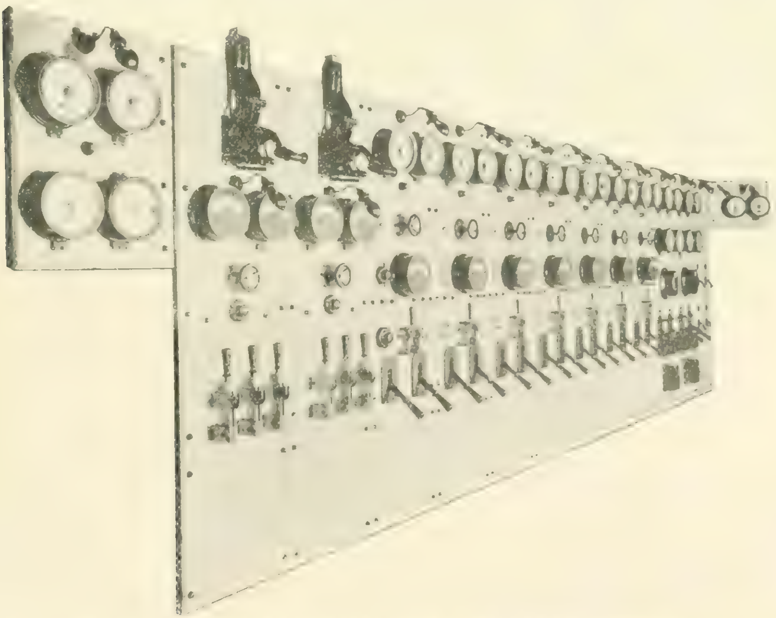


FIG. 24—A LARGE SWITCHBOARD FOR HIGH TENSION SERVICE

high as the convenience of the operator would allow, which made it necessary to place the field meters lower.

The appearance of a switchboard is a matter to be looked after carefully and yet the principle feature is easy operation. The meters must be well lighted and in such a position that the operator can see them distinctly when using the other apparatus. The switches and hand wheels must be placed within easy reach and in distinctive positions. The importance of leaving plenty of space be-

hind a switchboard is great in any case, even in low tension work, where all of the apparatus, except the connections, is on the front of the board. It is absolutely necessary in high tension equipments. In the first place the oil switches and the instrument transformers occupy a good deal of room. In the next place the wiring must be done with more care and spacing than with low tension work, and there are more wires to be taken care of. In the third place it is essential to be able to inspect the apparatus with convenience and safety.

At the left of the board shown in Fig 24 is a swinging panel which may be turned to a position at right angles to the board. Upon this panel three voltmeters and a synchroscope are mounted. The next two panels control the two exciters with the usual complement of apparatus. Each of the next seven panels contains the operating equipment for one alternator. This equipment comprises an ammeter, an indicating wattmeter, a field ammeter, a field rheostat hand wheel, a field switch, two handles for the non-automatic main oil switches, two synchronizing plug receptacles, a synchronizing lamp, an eight point voltmeter plug receptacle, and four ammeter plug switches.

The two oil switches are single-throw used as selector switches to connect the generator to either one of two sets of bus-bars.

The switches and bus-bars are mounted in a fireproof structure some distance from the board.

The two synchronizing plug receptacles connecting the synchroscope to either of the two bus-bars are directly over the switch handles so that the liability of throwing the wrong switch is small. Two transformer panels and a double high-tension feeder panel are next. Each of the transformer panels is equipped with three ammeters, a power-factor meter, an integrating wattmeter and an overload time-limit relay operated from two series and two shunt transformers, and the handles of two automatic oil circuit breakers.

Two high-tension feeders are controlled on the last panel, the controllers and indicating devices for electrically operated switches being the only apparatus mounted on this panel. Two frequency meters occupy the swinging panel at the extreme end of the board.

Fig. 25 is a partial diagram of connections of the equipment described above, showing the apparatus for one generator, one feeder, and for general use. As the instrument transformers are mounted in the fireproof structure with the oil switches, the leads to the instruments are rather long. They are cabled into con-

venient groups of three or four for the shunt and series transformers respectively and are drawn through iron conduit.

A voltmeter and frequency meter are directly connected to the transformers on each bus. The other voltmeter is connected

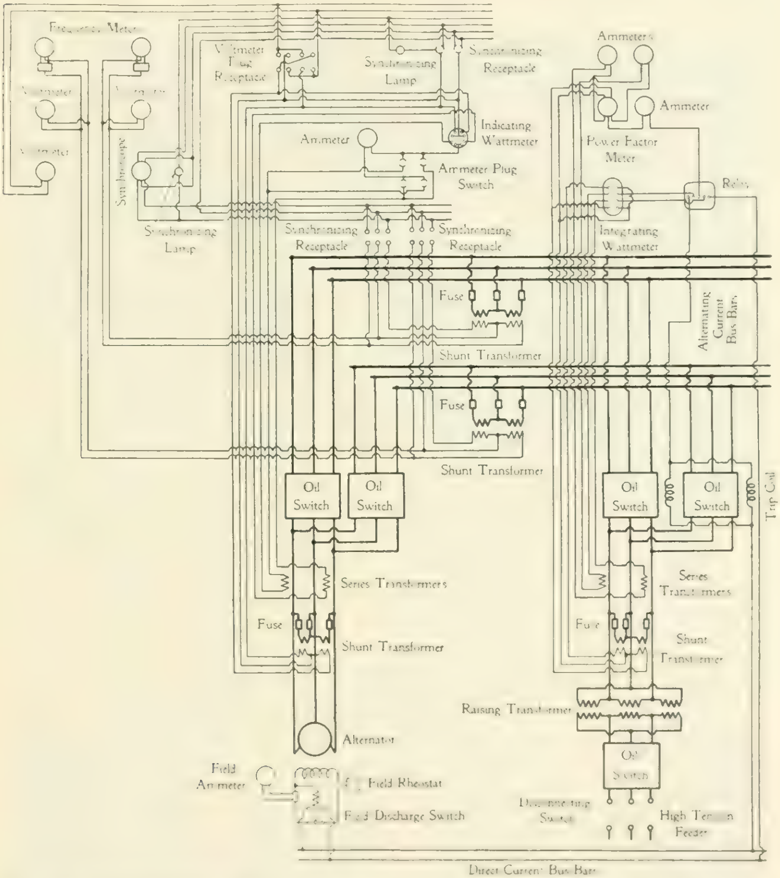


FIG. 25—CONNECTIONS FOR A LARGE SWITCHBOARD FOR HIGH TENSION SERVICE SHOWN IN FIG. 24

to bus wires which lead to the plug receptacles on each generator panel.

The synchroscope is a polyphase instrument and two six-point receptacles are provided to connect it to either of the two sets of bus transformers. In addition there are the regular plugs in the circuit from the generator transformers. With a single-phase in-

strument, two four-point receptacles on each panel are sufficient for the synchroscope connections.

The tripping coils of the automatic feeder oil switches may be operated directly from the series transformers, but in this case an overload time limit relay was used as shown.

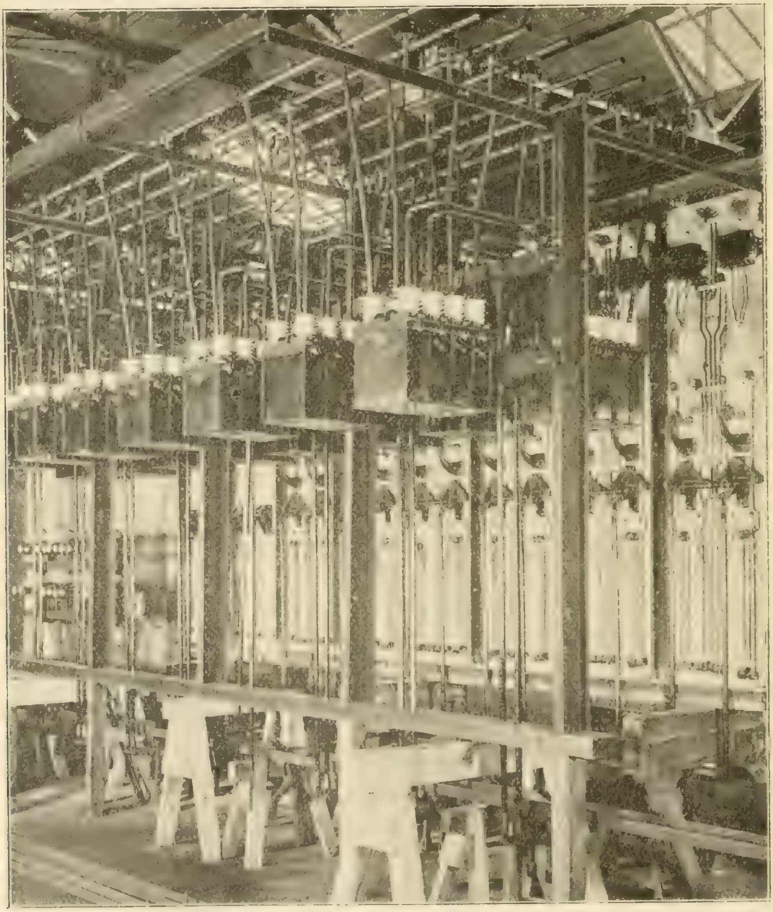


FIG. 26—REAR VIEW OF A LARGE HIGH TENSION SWITCHBOARD FITTED WITH SEPARATELY MOUNTED OIL SWITCHES OPERATED THROUGH CONNECTING RODS AND BELL CRANKS

An example of the use of separately mounted oil circuit breakers is shown in Fig. 26. This shows the rear view of a board designed for a double throw system like that shown in Fig. 24 but with the switches mounted on frame work directly behind

the panels. The handles, connecting rods, and bell cranks for operating the oil switches are clearly shown, also the supporting frame for the panels and the switches, the bus-bars mounted on line insulators, the main wiring to the switches, the instrument wiring on the panels, and at the left, some of the instrument transformers. The field rheostats and face plates for this board are mounted below the floor and are operated by sprockets and chains from the hand wheel and the bracket supporting it as shown in the illustration.

FACTORY TESTING OF ELECTRICAL MACHINERY—XIX

By R. E. WORKMAN

INDUCTION MOTORS—Continued

(5) Power Curves—The power curve of an induction motor consists of curves of horse power, apparent input; horse power, real input; horse power, brake output; power-factor; apparent efficiency; real efficiency; and speed. All of these are usually plotted against the mechanical torque output. The terminal voltage and the frequency of the supply are held constant.

As previously stated, there are three methods of finding these curves:

(a) Directly from a brake test.

(b) Calculated from the losses and a speed curve.

(c) Calculated from the losses by the aid of a special diagram.

(a) POWER CURVES CALCULATED FROM A BRAKE TEST

This test, though subject to the errors inherent in all brake tests, viz., those due to an unsteady load, is nevertheless very convenient in the case of small machines.

Preparations for Test—The motor is tested with the same outfit and connections used in taking the locked saturation excepting that water is required to keep the brake pulley cool. A jet of water is projected into the pulley, the heated water being removed by a scoop and a large hose.

Arrangements must be made to take simultaneous readings of the motor slip or speed and the generator speed.

The slip is measured by means of a slip indicator.*

Conduct of Test—The motor is started up as in the other tests, usually with a reduced voltage. The full-load torque is calculated from the full-load output and an estimated full-load speed. Five to seven torque values are then selected extending to about 25 per cent. overload and a full set of readings taken at each of these points.

The readings taken at each point are:—volts, amperes per phase, watts, torque, motor slip or speed, and generator speed. The voltage and the generator speed are held constant throughout.

As the brake load fluctuates considerably even though the tension is being constantly readjusted, it is necessary that the watts and the amperes should be read simultaneously and while the scales are exactly balanced. The speed or slip of the motor and the speed of the generator must be taken simultaneously. It is therefore apparent that the scale balance must be held steady while all the readings of any one point are taken.

The man who manipulates the brake has the most responsible task. With a good smooth brake strap, a true pulley, and plenty of water and grease he should be able to hold the load quite steady. He should give some sort of sharp signal at each moment the scales are exactly balanced and his hands are removed from the adjusting wheel.

A brake test is absolutely worthless unless the brake rigging is operating with a high degree of mechanical nicety and the man operating it has a painstaking temperament and a steady hand.

In addition to the power curves it is generally desirable to find the maximum or pull-out torque which the motor will develop.

Where the resistance of the secondary is very low the pull-out torque is considerably greater than the starting torque. In the case of large motors, the current taken by the motor when being pulled out at full voltage is very large. This is especially pronounced in the case of motors having secondaries of a very low resistance. It is therefore often advisable to take the pull-out at a voltage below the rated voltage of the motor. When taking a pull-out test the voltage is held constant at the desired value. The brake is slowly tightened while a balance is maintained on the scales by continual-

*See *The Electric Club Journal*, Vol. I., p. 590.

ly varying the weights. When the motor pulls out, that is, when it begins to slow down rapidly without further increase of torque, the readings of voltage and torque are noted. The moment at which the motor pulls out is best determined by listening to the humming or groaning sound. In the case of large motors, if this test is made too rapidly, the momentum will make the torque reading high; if made too slowly, the heating due to the heavy current will make the torque reading low.

Precautions to be Observed—In using the speed counter or slip counter, it is important to make sure that it is held in line with the axis of the shaft. Neglect of this precaution may introduce large errors in the slip readings. Often the speed counter is found running faster than the shaft. Be sure the brakeman has his hands removed from the wheel when he signals to read. Speeds should be taken for a full minute and with watches having clear cut second hands and dials. The line frequency should be steady.

The field of the generator furnishing the power should be well up on the saturation curve. It is impossible to get a satisfactory pull-out or lock reading, attempting to hold the voltage half way down the saturation curve. For example, if the 400 kw plant is furnishing power to a 60 cycle, 200 volt motor, it will be necessary to generate 400 volts and transform the generator voltage down to 200 volts instead of holding it at 200 with a weak field current.

Working up Results—The methods used may best be explained by reference to an example. The following readings were taken on the five hp. cage wound motor previously referred to:

			Speed			
Volts	Amperes	Watts	Motor	Generator	Torque	Corrected Motor Speed
200	11.24	1082	889	516	6	885
200	13.9	1880	872	516	12	869
200	17.9	2710	854	513	18	855
200	22.2	3580	844	516	24	841
200	26.8	4480	821	512	30	825
200	32.3	5520	801	513	36	802
200	40.6	6640	766	516	42	764
200	45.1	6980	745	515	45	742
200	48.3	7500	714	513	48	715

The mean generator speed is 514 r.p.m. equivalent to a synchronous speed of 900 r.p.m. on the motor.

The results deduced from these readings which are shown in Fig. 84 are:

(1) Speed-Torque Curve—Found from the speed or slip readings on the motor, the generator speed and the torque readings. Corrections often have to be made for small variations in the gen-

erator speed. This is done by multiplying the motor speed by the ratio of the correct generator speed to the observed generator speed. Where slip readings are taken on the motor, this correction is unnecessary, since a small variation in the generator speed will make practically no difference in the slip.*

(2) Apparent Horse Power Curve—Found by multiplying the amperes per phase by the voltage between terminals and by the constant $\frac{1}{746}\sqrt{3}$ in the case of three-phase motors, or $\frac{2}{746}$ in the case of two-phase motors.

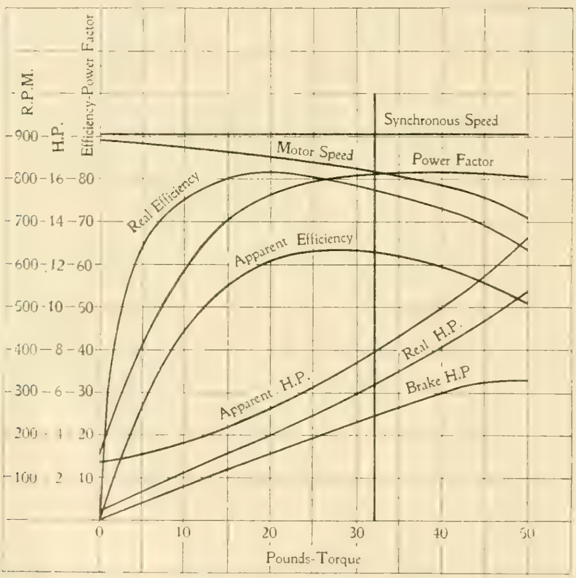


FIG. 84—POWER CURVES OF A FIVE-HP, TWO-PHASE, 200-VOLT, 60-CYCLE, EIGHT-POLE INDUCTION MOTOR. CALCULATIONS MADE FROM BRAKE TEST

(3) Real Horse Power Curve—Found directly from the wattmeter readings.

(4) Brake Horse Power Curve—Found from the speed and the torque readings. The brake horse power is the product of the speed, torque and the constant, $\frac{2\pi}{33\,000}$ equal to .0001902.

(5) Power-Factor Curve—Found from the curves of real

*See *The Electric Club Journal,* Vol. I., p. 590.

input and apparent input by taking the ratio of the former to the latter for each torque considered.

(6) Apparent Efficiency Curve—Found from the curves of brake output and apparent input by taking the ratio of the ordinates of the former to those of the latter for each torque considered.

(7) Real Efficiency Curve—Found from the curves of brake output and real input by taking the ratio of the former to the latter for each torque considered.

(b) POWER CURVES CALCULATED FROM LOSSES

The experimental data required for this test are:

(1) Primary Resistance.

(2) Running Saturation (watts and amperes plotted to voltage).

(3) Locked Saturation (watts and amperes plotted to voltage).

(4) A curve of speed plotted to amperes input.

The various data for this method may be found as in the preceding method, excepting the speed-ampere curve which may be more accurately obtained by belting the motor to a generator and loading the latter on a resistance. This manner of loading is much more steady than that obtained with a brake, and since the torque readings are not used the generator loading is preferable.

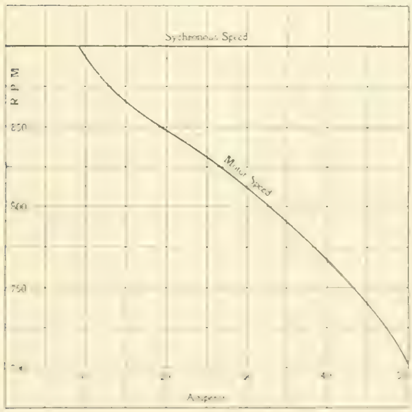


FIG. 85—SPEED-AMPERE CURVE OF THE FIVE-HP INDUCTION MOTOR UNDER CONSIDERATION

Speed-Ampere Curve.—This curve is plotted directly from the corrected readings. Fig. 85 shows such a curve for the 5 hp. motor under consideration.

EDITORIAL COMMENT

Theory and Practice

It often happens that what is regarded as abstruse and superfluous theory soon becomes the essential basis of every-day engineering work.

An admirable example is found in street railway operation. Not very long ago one of the essentials in the operation of a street railway was the handling of horses. The mechanical elements aside from track and trucks did not amount to much. With the advent of the electric railway came the power house with its boilers, engines, dynamos and switchboard; also motors and heavier car equipments. The electrical theory from the ordinary standpoint did not involve much beyond Ohm's law. Such things as lagging currents, power-factors and phases did not concern the electric railway manager any more than wireless telegraphy does today.

It was not long, however, before the alternator and the rotary converter became important factors in railways, both for heavy city service and for interurban lines. The rotary converter combined in itself most of the erratic elements of the synchronous motor, involving polyphase currents, leading and lagging current, hunting and the like. Not only this, but it had some limitations which a direct-current generator does not have. In other words, it combined in itself the critical elements of both alternating and direct-current apparatus. Transmission lines apparently departed from Ohm's law and indulged in induction and capacity effects which were often beyond the range of the imagination of the direct-current expert. But operation beyond the sub-station was still along the old lines. The alternating innovation was all back of the switchboard which supplied current to the trolley.

Now comes another innovation. Alternating current moves a step farther. The single-phase railway system brings the mysterious inductive drop and power-factor clear through to the motor. The idea of throwing its normal voltage on a motor without disastrous consequences or of short-circuiting the motor brushes without anything particular happening are rather startling to the old time electrical railway man.

In order to take up a new thing it is not so essential that one

be familiar with the particular facts and characteristics of operation as it is that he be well founded in the underlying principles upon which they are based. A clear, definite, physical, conception of alternating-current phenomena is the proper basis, for with this it is relatively easy to understand the working characteristics of the new system.

In almost every branch of electrical engineering advances are being made which call for a high grade of engineering knowledge and ability. Electrical engineering is progressive and the engineer will soon reach his limits who has not the foundation on which to build. Individual progress, however, depends only partly on preliminary education and training. It depends very largely upon the habits of mind and the ways of thinking, of the man himself. Progress depends upon progressive men and it is therefore the progressive, developing, expansive man who will be in the lead.

The Telluride Plant

Mr. Nunn's description of the Telluride plant, which is summarized in this issue of the JOURNAL, begins with the installation of the generators. This was not the real beginning. In fact many of the incidents mentioned by Mr. Nunn were only the sequel of the earlier chapters of the story which has not been written.

It happened to fall to my lot to have charge of the general layout of the apparatus, to determine the methods to be adopted, to design much of the auxiliary apparatus, to conduct the tests and to prepare the instructions for operation. The contract was closed about the first of September, 1890, and the apparatus was wanted before the winter snows. Some of the questions to be settled were these: Should generator or motor or both be self-exciting or separately excited, with or without composite winding? Should the starting motor be a split-phase motor, or one with a single winding to be started by hand? What type of switch should be used? The switches in ordinary use were jaw switches on wooden bases, and arc-light plugs mounted on wooden frames What method of regulation by the attendants should be adopted? If each effected his regulation by adjusting the field current to keep the voltage constant, there would be danger of over-charging one machine and under-charging the other. What type of fuse was suitable for opening the

circuit on a 3 000 volt synchronous system? The ordinary station fuses were not very reliable at 1 000 or 2 000 volts.

The answers to these questions are simple to-day in the light of experience, but fifteen years ago there was not experience, only apprehension. Suffice it to say that the problems were worked out in one way or another and that the operation of this system during its first few years would compare well with some more modern plants. In fact, it led to an increase in purchases of generators and of motors. The later operation was not so satisfactory as it was at first, for the difficulties in a synchronous system, particularly in one using single-phase currents, are apt to increase as the number of machines grows greater. There seems to be a sympathetic connection between the motors, such that disturbances or misbehavior on the part of one induces similar action on the part of others. A plant involving 20 times the voltage, 50 times the distance and 100 times the power may be laid out and installed to-day with less fear and trembling, and with less courage, particularly on the part of the purchasing company, than the historical installation at Telluride.

It is interesting to note that it was soon found at Telluride that the operation of a plant requires something more than machinery, particularly if it uses synchronous motors. Mr. Nunn saw to it that he built up a force of intelligent men. In fact the company with which he is connected has made the systematic training of men for its service one of its special departments.

Chas. F. Scott

Progress in Instrument Design

When alternating currents were introduced on a large scale the problem of producing a suitable line of instruments which would be as accurate and as satisfactory as the direct-current instruments then in existence, was very serious. This problem, in connection with other alternating-current problems, has been very satisfactorily solved during the last five years. The alternating-current instruments now upon the market compare very favorably in their operation with the direct-current instruments.

The introduction of alternating currents has led to requirements for new types of instruments owing to the fact that there are many quantities to be measured and comparisons to be obtained

in alternating currents which are not found in direct-current practice. Among these new instruments may be mentioned polyphase wattmeters, synchroscopes, frequency indicators, phase indicators, and instruments for measuring high potentials.

In the development of alternating-current instruments, the magnetic vane types of instruments were naturally those selected for making ammeters and voltmeters, and moving coil types for wattmeters. This was due to the fact that these types had already been pretty well developed for direct-currents and were suitable for alternating-currents with but slight modifications. The magnetic vane type was quite inferior to the permanent magnet or D'Arsonval type for direct-currents, and also was found unsatisfactory in many respects for alternating-currents owing to the additional errors introduced.

The advent of the induction type wattmeter for house service and its great success initiated a development of induction type indicating wattmeters, ammeters and voltmeters. The problems in these were somewhat more difficult than with the integrating meter, but they have now been solved in such a satisfactory manner that the alternating-current instruments of the induction type are fully the equal of the direct-current permanent magnet types, in reliability, accuracy and cost.

Paul MacGahan

Pull and Push

Some young men depend upon the direct personal influence of friends in official position for securing advancement. This method seems to them the only method, not only for themselves but for others—as they are apt to suspect that some particular favoritism underlies each advancement.

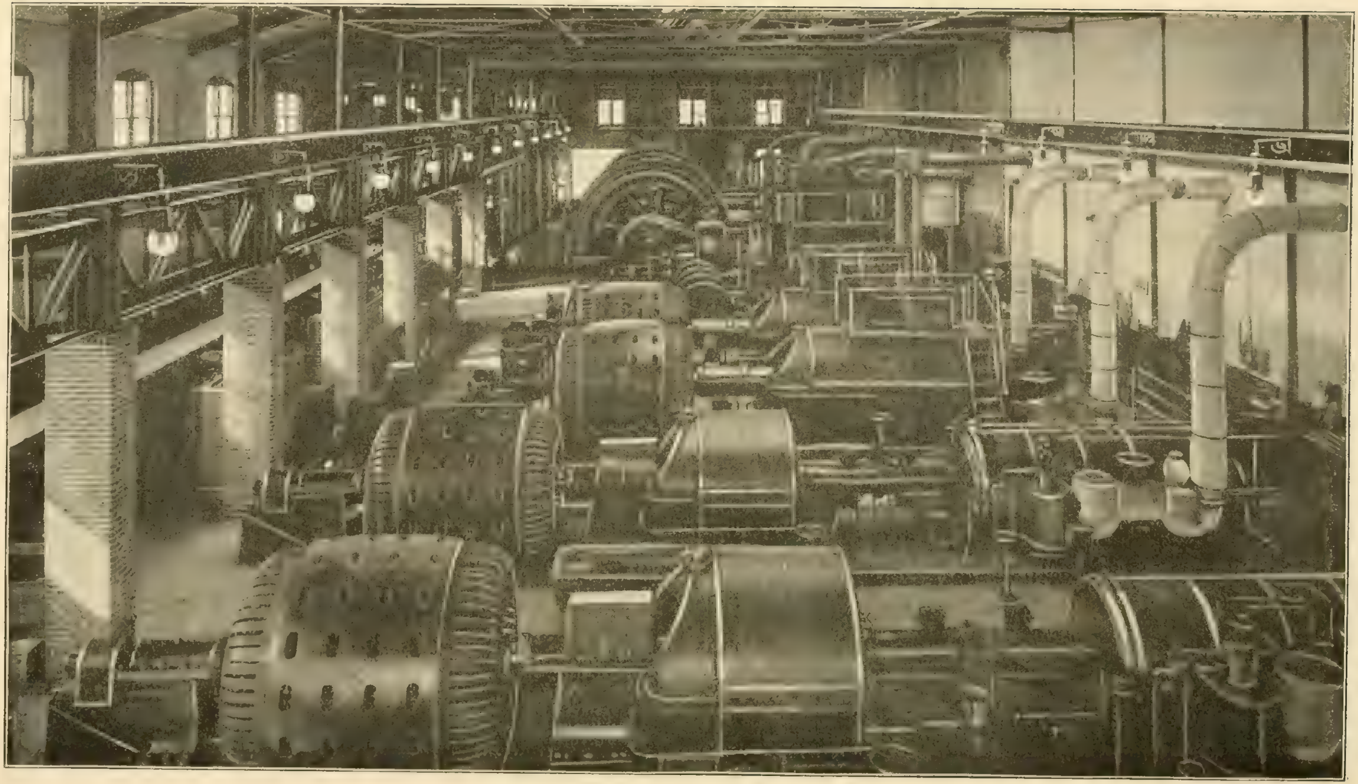
Some young men, on the other hand, seem to think that the only way to get on in the world is by vigorous activity on their own part in applying for new jobs or asking for an increase in their pay. They are sure they will be side-tracked unless they are insistent and persistent in urging their claims for something better.

There is a right and proper indorsement of a man's ability and fitness by those who know him, but it is quite different from pull. A measure of tactful aggressiveness is commendable in an ambitious young man, but it is quite different from discontented, restless, impertinent push.

Did you ever observe how many of the men about you—particularly those having positions of responsibility—are in their places because of their fitness for them? When a man is advanced, is it not usually because he has given promise of his ability by his past work?

There are two men who will probably not hold their jobs very long—one is the man who does not *make good*, the other is the man who does his work so well that he shows his capability for something more. Observe for yourself. Note the men about you and study their characteristics and see how efficiently they are doing their work. You can predict fairly well whether they will be doing exactly the same thing in a year, or something larger or smaller.

At a farewell dinner to a young engineer who was about to take a position of increased responsibility one of his associates said, "When I came to this company a year or two ago and found so young a man in so important a place I wondered whether he had a pull or was really *delivering the goods*. I soon found out."



FOUR 1 500 KW STEAM TURBINE UNITS

In power house of Philadelphia Rapid Transit Company at Second and Wyoming Ave., Philadelphia, Pa. Some Corliss units are seen in the rear of the station.

THE
ELECTRIC JOURNAL

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SINGLE-PHASE ALTERNATING-CURRENT CAR CONTROL

R. P. JACKSON

MASTER CONTROLLER

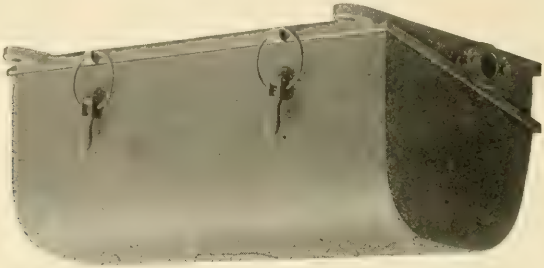
The advent of the Lamme single-phase motor and its use in equipments of all sizes from single truck cars furnished with two 50 hp motors to large locomotives of over 100 tons weight, introduced several new problems of control.

Direct-current car controllers have been undergoing development for many years and in the larger equipments where multiple control is provided they are still progressing. The present standard apparatus for the control of alternating-current motors, however, is all of recent origin and design. Starting devices for induction motors have been built for some time, but switches to make and break alternating current many times a day and under all kinds of load involve a departure in design from previous practice.

Consequently considerable attention has been given to the induction regulator for the control of single-phase motors. It has been found, however, that the fine gradation of voltage given by the regulator is not required for ordinary operating conditions. With switching devices properly designed, the difficulty of handling heavy alternating currents proved to be less than was anticipated. While the induction regulator may be required under some special conditions, the form of control described below offers greater simplicity and lightness and with it the cost of the car equipment may be materially reduced.

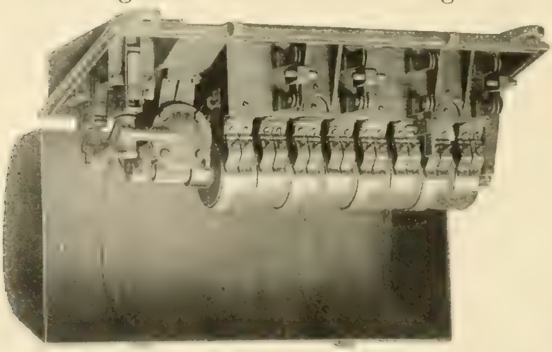
One great advantage which the single-phase system possesses is that the power may be transmitted to the car through a

high voltage trolley. The standard voltage for this purpose is 3 300, although double that potential has been used in some cases for the heavier work. This high trolley potential of course necessitates the use of a transformer on the car as the motors are



COMBINED REVERSER AND CUT-OUT AS SUSPENDED UNDERNEATH THE CAR

wound for a comparatively low voltage. Further, as the rail is employed for the return circuit, one side of the transformer which is preferably of the single winding or auto-transformer type, is grounded. The potential of the transformer winding with reference to the ground is therefore zero at the grounded end and increases with each turn of its coils to the trolley voltage at the high tension end. Obviously the most simple control is to be obtained by connecting the motors between the ground and the de-



COMBINED REVERSER AND CUT-OUT, SHOWING CONTACTS AND CUT-OUT SWITCH, SUSPENDED UNDERNEATH THE CAR

sired points of this transformer winding. The required voltage points may be brought out by means of taps or leads from the transformer winding and in their use the proper variation of voltage for starting the motors and the regulation of their speed is

directly obtained without any waste of energy in rheostats or the use of further translating devices.

With such a method of control available the motors may all be placed permanently in multiple and any series-parallel arrangement becomes a useless complication. Placing all the motors in parallel offers many advantages in itself as it subjects the motors to a uniform and minimum insulation strain and any one motor may be cut out without disturbing the operation of the others. The motors also may all be connected to ground and the connections of any one motor are the same as all the others.

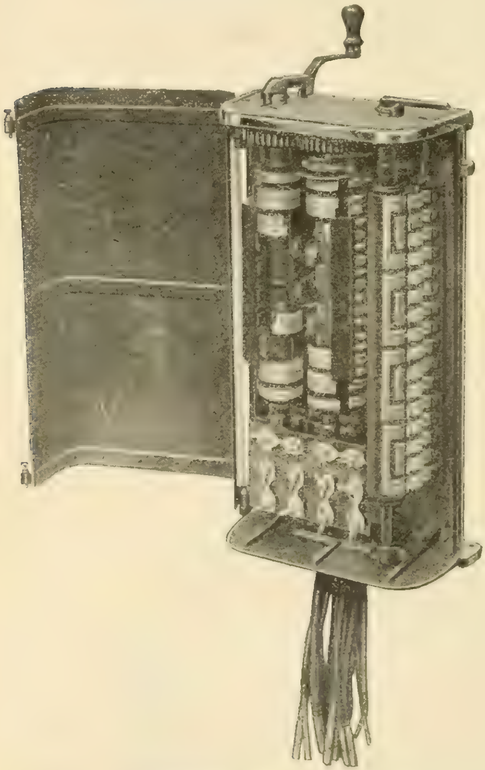
DRUM TYPE CONTROLLER FOR A 50-HP MOTOR EQUIPMENT

While the auto-transformer designed with the proper taps will furnish the desired voltages, in order to step from one tap to the next one without opening the circuit or short-circuiting the winding on the transformer between the taps, it is necessary to employ some device such as a preventive resistance or preventive coil to take up the intervening momentary voltage. Where it is desired, as in car control, to run on a number of different points, the preventive coil has several advantages inasmuch as it has no choking effect or rheostatic losses while on running points and its own losses are insignificant.

The schematic diagram for cars shows the succession of connections for this form of control and two types of apparatus have been developed to accomplish these results. They resemble similar apparatus for use with direct-current motors.

The drum type of controller, on account of its simplicity and freedom from trouble as well as cheapness, is generally used on equipments up to and including four 75 hp motors when multiple unit control is not required. Externally this controller resembles the ordinary direct-current type. There are, however, no magnetic blow-outs or series-parallel connections. Experience has shown that for all ordinary purposes, five points of control are ample and give a smoother acceleration than is usually obtained with direct-current motors. Six or more taps are brought out

from the transformer winding from which a suitable selection is made for the operation of the motor. The current for the motors being drawn from the middle point of the preventive coil, it must be received in nearly equal amounts through each half and so also from each of the transformer taps. When the controller is moved from one notch to the next higher notch connection is broken with the lower tap and made with a higher one. The voltage applied to the motors is thus changed from a lower to a higher value without interrupting the current to the motors.



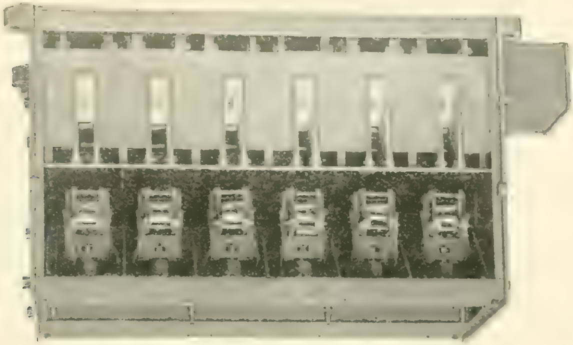
DRUM CONTROLLER FOR A FOUR 50 HP MOTOR EQUIPMENT

With this type of control heavy currents may be broken many times without danger or damage, and the motorman may run on any point as long as desired. Every notch on the controller is an efficient running notch. The motorman soon learns to accelerate his car and then drop back with his controller to a lower point which will just give the desired speed. In this way the third or fourth point may be adjusted for the ordinary running point while the last point is reserved for hill climbing or extra high speed.

With direct-current control but two such running points are provided and if the controller is at the full multiple position and it is desired to change to series, it is necessary to return to the off position and throw on again.

On larger cars where multiple operation of several cars from one master controller is required, the control is obtained by means of switches operated by compressed air and of a general

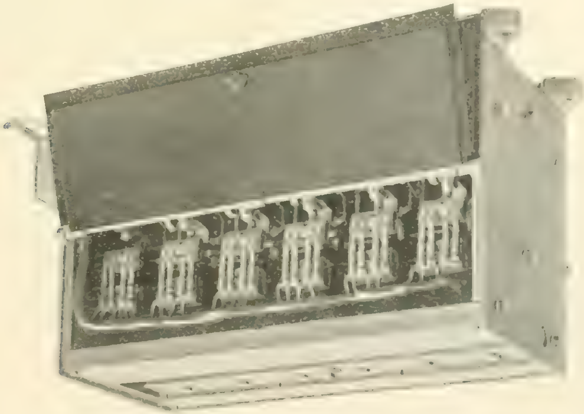
design similar to the switches used in direct-current multiple control. The method of operation is substantially the same as that



UNIT SWITCH GROUP. FRONT VIEW SHOWING SWITCH CONTACTS AND VALVE MAGNETS

used in the drum controller. · A magnetic blow-out is necessary for the proper operation of the switches.

The air to close the unit switches is admitted by valves operated by magnets which receive their current from the 50 volt tap on the transformer. This obviates the need of a storage battery to furnish current for the valve magnets. Each switch is



UNIT SWITCH GROUP. REAR VIEW SHOWING INTERLOCKS

opened by a powerful spring similar to that in use on switches for direct-current control.

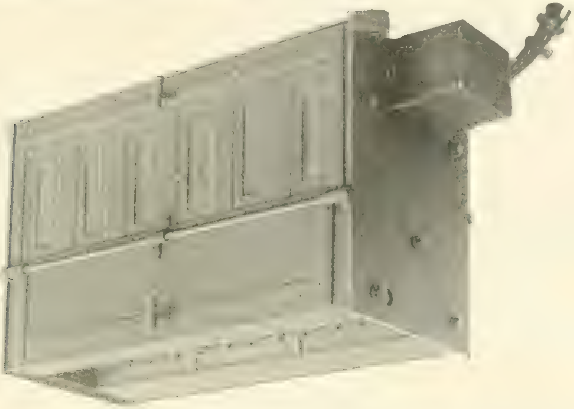
The reverser is of drum type and air-operated in a similar manner to the unit switches. Each motor is reversed independently and may be cut out by opening a knife switch. This reverser is mounted near the side of the car, rendering these switches readily accessible by opening the reverser cover. As before noted, the motors being in parallel, the cutting out of one does not disturb the others. The operating characteristics of the unit switch control remain the same as for hand control.

The transformer which receives the power at 3 000 or 3 300 volts delivers it to the motors from taps giving 140 to 270 volts approximately. It may be either oil insulated and self cooling or of the air cooled type. If of the latter kind a blast of air is maintained by means of a small motor-driven fan mounted in the hood at one end of the transformer. The motor for this fan also receives its power from a low voltage tap on the transformer. This application of current indicates one great advantage of the alternating-current system—that any desired voltage may be obtained simply by bringing out a lead from a suitable point in the winding of the transformer. For this reason, small motors, valve magnets, etc., may be wound for whatever voltage is most economical and convenient. Thus, the well-known flexibility and simplicity in manipulation which is characteristic of alternating current, reappears even in minor details.

Overload protection is provided in all cases. With hand control, fuses in each motor circuit are mounted in the base of the controller. Removing one of these fuses cuts out a motor and if the motor becomes damaged, the fuse blows and cuts it out automatically. While this method may be used with unit switch control also, it has been found preferable to provide a relay in connection with the switch group which carries a coil in series with the motor circuit. In case of an overload, this relay opens the circuit to all the valve magnets. The unit switches, therefore, also open at once. When the master controller handle is returned to the off position, the relay resets itself automatically. In all cases, a substantial fuse should also be placed in the trolley circuit.

A further development of this method of control is applicable to heavy locomotive work. A similar sequence is maintained in the opening and closing of the switches and the result of each change is that the motor voltage is increased or decreased by the amount of one step between transformer taps. In this man-

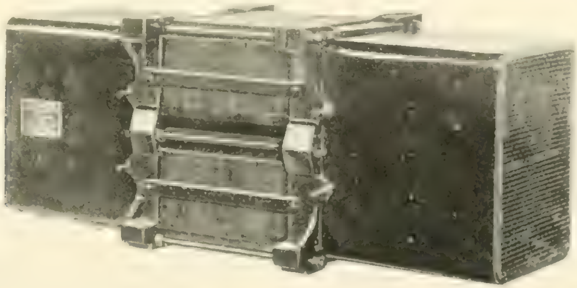
ner, the motor voltage may be shifted up or down without interruption of the current and without causing short-circuits between transformer taps. Interlocks prevent improper switches closing



SWITCH GROUP COMPLETE, WITH OVERLOAD RELAY SUPPORTED UNDERNEATH THE CAR

at the same time and short-circuiting a step of the transformer winding.

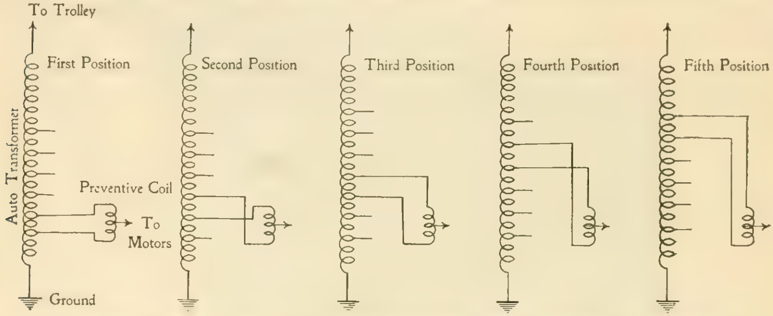
It has been found that alternating current up to 500 or 600 volts is much easier to break than direct current of the same power. There is, moreover, no such tendency to flash to ground or to short-circuit and maintain an arc over long distances as is manifested by direct current. The alternating current, however, manifests its usual tendency to develop hysteresis and eddy current losses and these must be taken into consideration in the de-



AUTO TRANSFORMER

sign of the apparatus. Herein lie the differences between control apparatus for direct and alternating current. Switches for the first must provide sufficient room for the expansion of the arc

and the escape of the copper vapor. The blowout must be able to disrupt the arc of a circuit which exhibits a powerful tendency to maintain itself. With low voltage alternating current, however, these difficulties become much less, but careful provision



CONNECTION TO THE AUTO TRANSFORMER FOR DIFFERENT POSITIONS OF THE CONTROLLER

should be made to provide against excessive generation or concentration of heat due to hysteresis and eddy currents.

In conclusion, it may be said that, taking the system as a whole, the number of efficient running points and the general simplicity and symmetrical nature of all the connections, combined with the low voltage of the motors and a certain elasticity

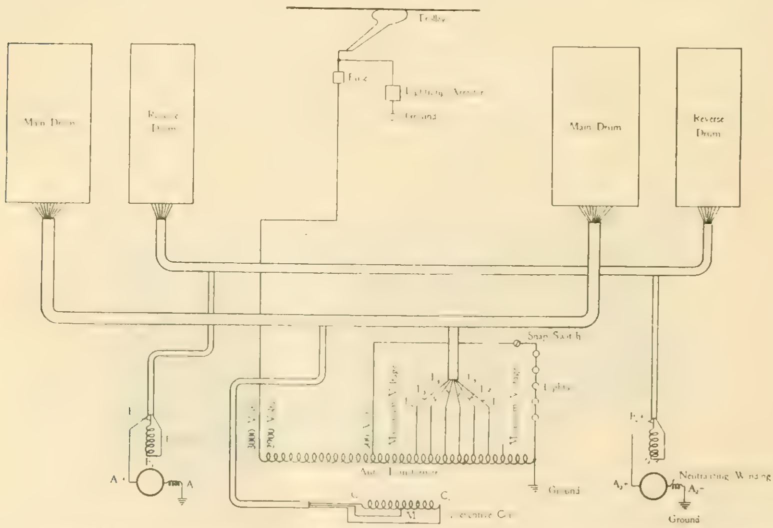


DIAGRAM OF WIRING ON CAR EQUIPPED WITH TWO SINGLE-PHASE MOTORS

which permits fewer points of control, render this system admirably adapted for the operation of cars or locomotives of any size.

THE PRACTICAL UTILITY OF TECHNICAL TRAINING*

WILLIAM BARCLAY PARSONS

In 1870 there were less than half a dozen institutions in the United States where a good technical education could be had and the number of students was small. To-day there are no fewer than 43 such institutions, with over 23,000 students enrolled.

Before considering the practical value of technical education let us define what is an engineer and what is the vocation known as engineering. The word "engineering" is used here in its broadest sense, including all branches of professional work in applied science or construction. The word "engineer" is not, as is popularly supposed, derived from the word engine, a machine. There were engineers before steam was practically applied or before the development of engines in the modern acceptation of the term began. Both the words "engineer" and "engine" come from the same derivation, the Latin "ingenium," whose prime meaning is "natural quality, character, genius," and it in turn is derived from "gegno" —to produce. The engineer is, therefore, a man of "natural quality"—one capable of producing. The early engineers were military men engaged in fortifying cities and constructing battering rams and other engines of war. The first man to use the term "civil" engineer was John Smeaton, the eminent designer and constructor of the first Eddystone lighthouse, that guided safely into the harbor of Plymouth the East India merchantmen of the 18th century. He adopted this appellation to distinguish himself from his confreres as one working, not in military, but in civil undertakings. The profession of engineering, in its broadest scope, was later defined by Thomas Tredgold, when founding the Institution of Civil Engineers, as being "the art of directing the great sources of power in nature for the use and convenience of man." It is difficult to imagine a field of work of higher order, of wider scope, and for which a more complete previous technical training is essential.

The powers of nature, those great and mighty forces that surround us, that sustain and govern not merely our own small earth but the whole universe; powers that are without limits as to time and space, whose laws never vary, whose manifestations may under-

*Abstract of an address before the National Educational Association.

go change but which never suffer loss, and which are the only things that we have cognizance of that are of perfect truth—these forces in all their might, from the great energy of the engine capable of lifting mighty weights, or the violence of an explosive rending mountains of rock, to the gentleness of the watch spring in your pocket, regulated to a variation of less than a second a day, are by the study of the engineer controlled and directed for the use and convenience of his fellow men. How little did Smeaton foresee the development of civil work, to which he applied a designative title! How little did Tredgold realize the far-reaching effects of a calling to which, it is true, he gave unlimited bounds! The responsibility of educating men who are to follow Smeaton, who are to realize the ideals of Tredgold, who are to understand, direct and make useful the powers of nature, rests upon such as you who make up this audience. It seems but necessary to repeat that definition of engineering which in simplicity of language, in directness of thought, in broadness of conception, has never been excelled, to at once answer the question whether such education is better given in special technical colleges or in the offices of some one practitioner. What are these powers of nature? They are not only those that we see or feel every moment—light, heat, steam, gravity, but also those studied by the electrician, by the chemist, by the physicist, by the geologist, and by the other disciples of pure science; those intricate forces that, whether matter consists of many or few elements, give it such a manifold and diversified character. When the total of human information of these several branches of science was comparatively limited, when the engineer could depend largely upon precedent, when progress was made by short and careful steps, it was possible for a sufficient education to be acquired under the tutelage of a single man, leaving it to the inherent genius of the pupil to self-develop. With, however, the vast and constantly broadening field of modern scientific knowledge, it is quite impossible for one man, or such a limited group of men as one office may contain, to impart to the young student the requisite instruction in all the properties of the forces and materials of nature that he should have as a general frame-work of his professional education. Although engineering, like medicine, law and the other learned professions, is divided into separate branches, nevertheless the modern engineer must know something of machine design, of electricity and its practical application, of hydraulics, transportation, structural construction, together with physics, geology and metal-

lurgy. If such a structure be built on the solid foundation of a good education in the liberal arts, so much the better will it be, and obviously such a preparation can only be given in an institution with a corps of specialists. It seems a contradiction to say that as any profession becomes more specialized at the same time it becomes broader, but as a matter of fact the range of subjects to be studied does become wider. It is not necessary, in fact it is impossible, for any one to become expert in all branches; yet so interdependent are the several divisions, so interlocked are the various nature forces that some knowledge should be had of many subjects and much knowledge of few.

I gave you above numerical statistics of the growth of our technical colleges as an instance of the practical success of such education. Educational statistics of the engineering forces engaged in building the rapid transit subway of New York City were compiled and are both interesting and equally suggestive, as showing the extent to which technical training is availed of. The staff of engineers numbered about 200 at any one time, exclusive of inspectors, and was divided into three classes: the executive, or those engineers holding positions of responsibility, and who were called on for original thought in designing as well as for ability in execution; the assistant engineers, holding positions of less trust, men of less experience carrying out the orders of their superior officers, though still with responsibility; and third, the rodmen, those just beginning engineering work, called on for no originality, but acting entirely under instructions. All of these positions, except those in the first class, were filled after competitive civil service examination. Of the first two classes 86 per cent. were college graduates from our leading institutions, while of the third, where such education was not in any way a necessary requirement, not less than 58 per cent. had passed through some college of recognized standing.

During recent years we have been frequently admonished to lead "The Strenuous Life" by no less a person than the President of the United States, who has always been a vigorous exponent of his own doctrine. More recently an eminent French divine has been preaching the antithesis to "The Strenuous Life," namely "The Simple Life." Judged from the cold standpoint of practicality, is either right? Should either "The Strenuous Life" or "The Simple Life" be our maximum? Does either as an ideal satisfy in full all the requirements of life? Strenuosity suggests, and may be nothing more than energy for good or for

evil, vigor whose force, acting without guidance, produces no useful effect and entirely fails to come up to the meaning of "engineering," which is character, and the underlying motif of Tredgold's definition, which is force directed for the benefit of man. Simplicity, on the other hand, preached as a doctrine, calls to mind a gentleness deficient in vigor, or possibly a timidity that shuns a contest with the hard, unsympathetic conventions of life and an avoidance of the necessary and entirely proper complications that are an inevitable concomitant of modern development. Life itself is involved; everything about us is vast; and nature, with its sources of power, is complicated beyond human grasp, and all to an extent for which simplicity alone fails to present a satisfactory solution as a life guide. We need force, we need a vigorous force; we need that direction and avoidance of the unnecessary which is simplicity, but with either one alone there is something lacking. Instead of great force and latent energy without control, instead of quiet gentleness, or of power of control without vigor to be controlled, what we need is force and energy applied where necessary and always under control, always working to a definite purpose, and at the same time avoiding complications and unnecessary friction. That is, to have a life whose great underlying motif is effectiveness, and instead of speaking of the strenuous life or of the simple life, let us have before us as a doctrine "The Effective Life." What we need is not merely a man who acts, but one who does; that is, one who will do what he has to do regardless of intervening obstacles. Efficiency and effectiveness are the keynotes of success in actual life. They are also the lessons taught by every parable in the New Testament, even if that work is regarded as a code of ethics, and they form the spirit of that stirring definition of engineering which is based on the direction of the vital forces of nature and the doing of things for mankind.

Efficiency is the practical underlying principle in the work of technical education. In no other walk of life is actual efficiency so essential as in engineering. In other lines there is a place for the student, for the didactic, for him who would turn to his book to gather wisdom, but not so in technical work. Here there must be the man to do—to take those great and mighty forces and make them do effective work. Unless he can so stand up and do that, the engineer cannot succeed.

We are all cognizant of the great results already achieved by technical development, but have you ever paused to take the meas-

ure of any one example, to analyze some one of the results that we see daily produced and to estimate what it means? Let me give you one example, to which I have referred on other occasions, but which is not out of place here. You have all seen some ocean liner pass majestically to sea out of the port of New York, but have you ever thought of what that ship has been designed to do, and the amount of energy, expressed in simple language, that is required to propel her from shore to shore? You see the many decks, the several funnels and the tall masts. Below the water and out of sight there is still more than what is visible above, but all is so adjusted that no matter how buffeted by the storms the ship will always be stable and will come back to a vertical position. Longitudinally, the great ship of 800 feet must be structurally designed to be supported at one moment on waves at bow and stern and yet resist breaking in two at the middle, and at the next moment be supported by a wave in the middle, only to resist breaking in two in the opposite direction. To drive this great mass, whose weight is 40,000 tons, through the water at railway speed requires a force rated at 50,000 hp. So stated, it means nothing, but as each horse power is equivalent to one and one-half ordinary draft horses, and as each of the latter can do the work of eleven men, which, however, can work for only eight hours a day, thus requiring three sets of men, there would be needed to take the place of the same energy in the ship no less than 2,500,000 men. Here in one single case combined we have an illustration of great static stability and enormous dynamic energy, and the whole is an excellent illustration of efficiency. The structural strength and the compressed energy of the ship is strenuosity in the extreme, but a vigorous strenuosity under absolute control, and that control by one man at a throttle wheel is simplicity itself. Either one without the other is valueless; together they make the vital principle of which I spoke—efficiency.

INSULATION TESTING*

C. E. SKINNER

Among the tests which are regularly made to determine the quality of a piece of electrical apparatus is that known as the disruptive or dielectric test on the insulation. Modern practice indicates the desirability of making these tests on the materials on the parts of the apparatus, and on the completed apparatus. The users of electrical machinery frequently include such tests among those which must be made for the acceptance of the apparatus. The American Institute of Electrical Engineers has recommended a schedule to be followed in the making of dielectric tests, this schedule setting the voltage limits, but not indicating apparatus and methods.

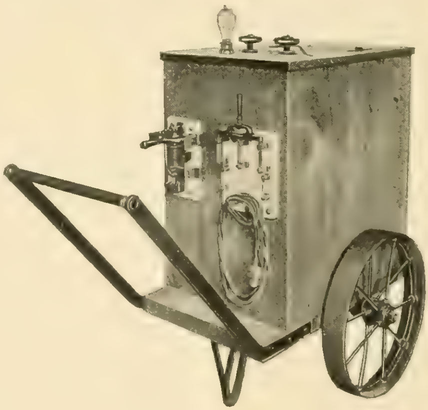


FIG. 1—5-KW, 10 000-VOLT TESTING SET

It will be the writer's endeavor to discuss brifly the elements that should be considered in the design, selection and use of apparatus for making dielectric tests.

TESTING APPARATUS

By far the greater part of such tests are made by means of step-up transformers. The static machine may be employed to advantage in some cases, and occasional tests are made by the use of direct current such as may be obtained from an arc-light machine; but as these cases are special, they will be omitted from the discussion, and only testing apparatus employing alternating current, either direct from the generator or through step-up transformers, will be considered.

In the design and selection of apparatus for making disruptive

*Read before the National Electric Light Association at its twenty-eighth convention, held at Denver-Colorado Springs, Col., June 6-11, 1905.

tests a number of points must be taken into consideration, among which are the following:

(1) Maximum testing voltage.
(2) Frequency of the testing circuit.
(3) Static capacity of apparatus to be tested.
(4) Variation of the testing voltage.
(5) Measurement of the testing voltage.
(6) Provision for locating faults.
(7) Portability of testing apparatus.
(8) Rating of testing transformers.

The items above will be discussed in detail in the order given.

(1) MAXIMUM TESTING VOLTAGE

The maximum testing voltage required depends on the nature of the material or apparatus to be tested. For the lower voltage apparatus, the testing voltage is usually several times the normal rated voltage of the apparatus. For the higher voltages, the testing voltage is rarely much more than double the normal rated voltage. In testing materials, almost any voltage or any range of voltage may be required, from a few hundred volts to 100 000 or 150 000 volts. For direct-current street-railway work, tests above 5 000 volts are rarely required, and tests from 2 000 to 2 500 volts are more common on finished street-railway work. Apparatus for 2 000-volt lighting service requires tests of 4 000 to 10 000 volts. In high-tension transmission work the test is usually from one and a half to two times the normal rated voltage of the apparatus. The highest e.m.f. in use at the present time for long-distance trans-

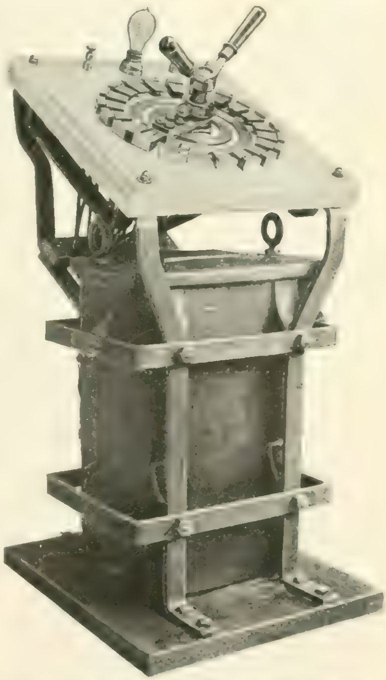


FIG. 2—25 KW REGULATING TRANSFORMER, GIVING 5 PER CENT. STEPS

mission work is approximately 70 000 volts. Tests requiring double this voltage are not at all uncommon.

When the investigation of insulating materials is to be undertaken, testing apparatus giving any voltage up to 150 000 will find frequent use, and for a complete understanding of the work, occasional tests of 200 000 to 250 000 volts may be required on special insulators or combinations of insulation for the higher voltage service. Testing apparatus capable of giving half a million volts or more is merely a scientific curiosity at the present time. Tests

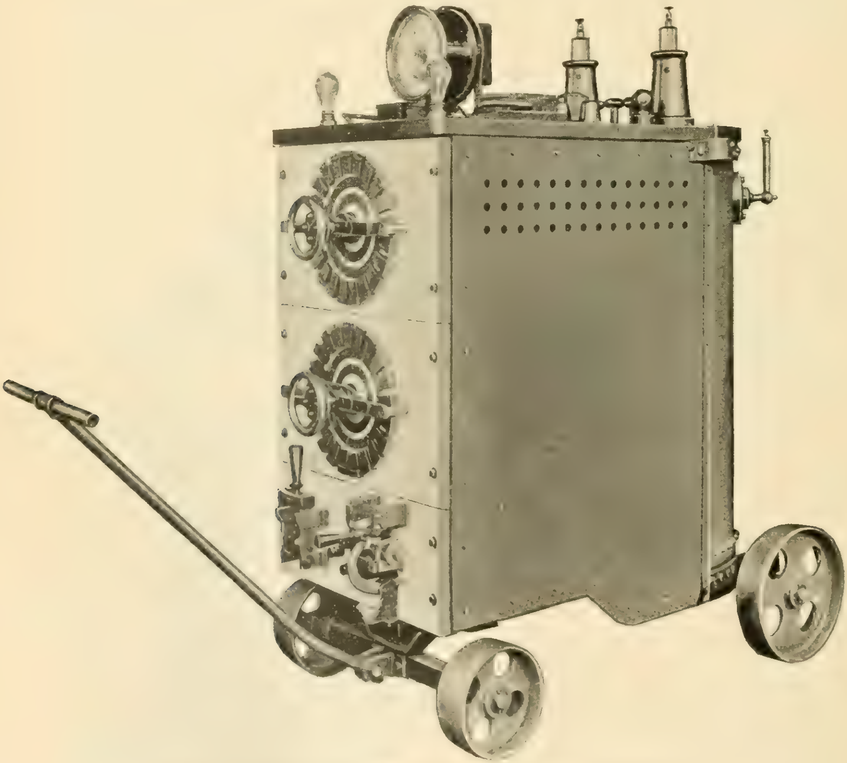


FIG. 3—30 KW. 30 000 VOLT TESTING SET COMPLETE

of 100 000 to 150 000 volts will cover any commercial work, even to the most exacting line insulator tests, and 250 000 volts should be sufficient for any investigation necessary in connection with commercial work. A well equipped high-tension laboratory should have apparatus capable of giving any electromotive force from a few hundred volts to the commercial maximum mentioned above.

The following table gives a list of maximum testing voltages suitable for various classes of work, together with the capacity in kilowatts which will be found sufficient for most work for each maximum voltage. Special work, such as cable testing, may require a greater transformer output, as will be discussed later.

Maximum Testing Voltage	Capacity in Kilowatts
2 000	1
6 000	3
10 000	5
30 000	30
50 000	50
100 000	100
150 000	150
250 000	250

The above are arbitrary divisions that have been found convenient in practice. The ratings given are the continuous ratings based on temperature rise.

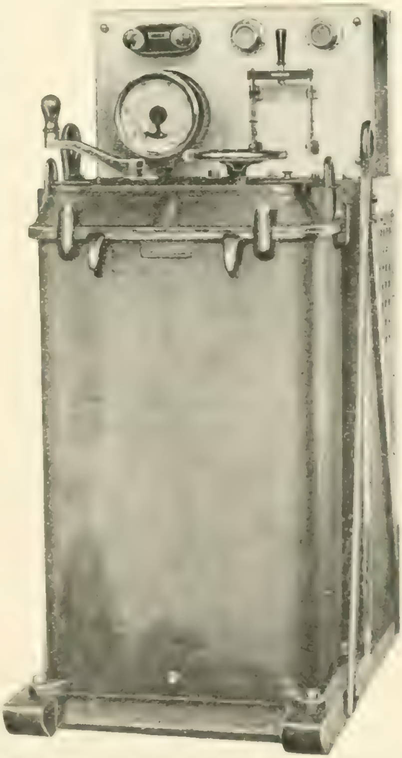


FIG. 4—250 KW. DOUBLE DIAL REGULATING OUTFIT COMPLETE EXCEPT TESTING TRANSFORMER

(2) FREQUENCY OF THE TESTING CIRCUIT

The frequency of the circuit on which a testing transformer is used determines in some measure its size for a given output—the lower the frequency, the larger the transformer required. A more important consideration governing the output for a given test follows from the fact that the amount of charging current to a piece of apparatus considered as a condenser varies directly as the frequency of the testing circuit. Consequently, the higher the frequency, the larger must be the

testing transformer for making tests on apparatus having a given capacity in microfarads and at a given voltage. Furthermore, the dielectric loss in insulation at a stress approaching the disruptive strength also varies approximately as the frequency, requiring additional testing capacity where this feature becomes a measurable factor.

It may be stated, therefore, (1) that for a *given output*, the lower the frequency, the larger the transformer required, and (2) that for a *given condition of test* a larger output testing transformer will be required for high than for low frequencies.

(3) STATIC CAPACITY OF APPARATUS TO BE TESTED

Small samples of insulation require but a very small output in the testing transformer, but with large machinery or cables a much larger output is required, on account of the current necessary to charge the apparatus or cable, considered as a condenser. The formula for the flow of current to a condenser when a sine wave electromotive force is applied to its terminal is as follows:

$$I = 2\pi \times 10^{-6} \times E \times C \times N$$

Where I = current in amperes,
E = volts,
C = microfarads,
N = cycles per second.

The charging current therefore varies directly as the frequency, directly as the voltage, and directly as the static capacity; and as apparent energy is equal to current multiplied by voltage, it follows that the apparent output of the transformer required must vary directly as the frequency, directly as the square of the voltage, and directly as the static capacity (in micro-farads) of the apparatus under test. Little or no additional transformer capacity is required for ordinary testing beyond that supplying charging current as shown by the formula above, and, with the small additions noted below, the output of a testing transformer may be based on the formula given, when the static capacity of the apparatus to be tested is known.

There may be slight I^2R losses in poor insulation due to current actually flowing through it, but the amount will be very small and practically negligible. The dielectric loss in the insulation is usually relatively small as compared with the charging current, and for all practical purposes it may be left out of consideration in the design of testing transformers.

Measuring devices, such as a direct-reading type voltmeter, in series with a resistance, on very high-tension circuits may take a sufficient amount of power to require consideration. For example, an ordinary alternating-current voltmeter in series with the necessary multiplying resistance on a 100 000-volt, 25-cycle circuit will require approximately six kilowatts to operate the voltmeter at full scale deflection.

The requirement of the Committee on Standardization of the American Institute of Electrical Engineers relative to transformer output required in dielectric tests is, that "the source of alternating e.m.f. should be a transformer of such size that the charging current of the apparatus as a condenser does not exceed 25 per cent. of the rated output of the transformer." This requirement seems to be based on some idea that there will be an undue rise of potential in the testing circuit unless the testing transformer output is very large. This is not borne out in practice, and it is the writer's observation, confirmed by that of others, that satisfactory tests can be made up to the full current rating of the testing transformer if the testing voltage is measured in the high-tension circuit. Modern testing transformers are as well designed as transformers for other purposes, and the American Institute of Electrical Engineers' requirement would frequently necessitate the use, especially in cable testing, of a testing transformer having an output greater than is usually available for such work.

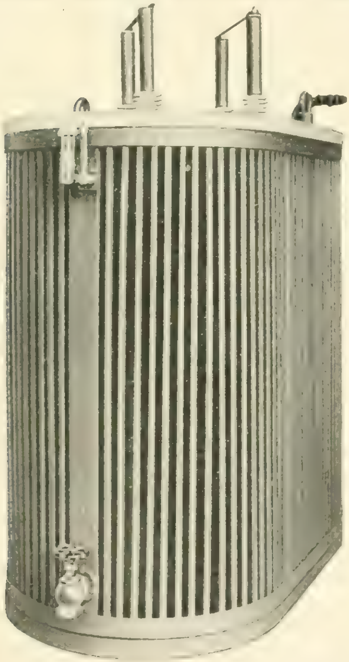


FIG. 5—200 KW. 150 000 VOLT TESTING TRANSFORMER. TWO HIGH-TENSION VOLTAGES

As examples of the minimum capacity that could actually be used, giving full rated load to the testing transformer, the following may be cited: The first 5 000-hp generators for the Niagara Falls Power Company have a capacity of approximately 0.3 micro-

farad. The test voltage was 6 000, and the minimum testing capacity required at a frequency of 25 cycles would therefore be 1.7 kilowatts. The 5 000-kw generators of the Interborough Rapid Transit Company have a capacity of approximately 0.6 micro-farad, and the test voltage was 25 000, requiring, therefore, a testing transformer of at least 50-kw capacity at a frequency of 25 cycles. An underground cable having a static capacity of one micro-farad and

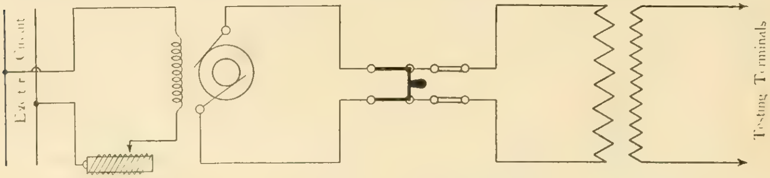


FIG. 6

Voltage regulation by field rheostat of generator. Range of testing voltage, from 50 per cent. below to 25 per cent. above normal rated voltage of generator, or from approximately 25 per cent. to 100 per cent. of the maximum voltage of the testing transformer. Suitable for all classes of work and for all capacities of testing transformers

tested at 20 000 volts, 60 cycles, would require a testing transformer of 150-kw capacity. A test at 40 000 volts on the same cable would require four times this capacity, or 600-kw, and a test at 60 000 volts would require nine times this capacity, or 1 350-kw, as shown by the formula given above.

(4) VARIATION OF THE TESTING VOLTAGE

There are three principal methods of varying the testing voltage when making dielectric tests. These are as follows:

(*a*) *By varying the field of the generator.* This method as-

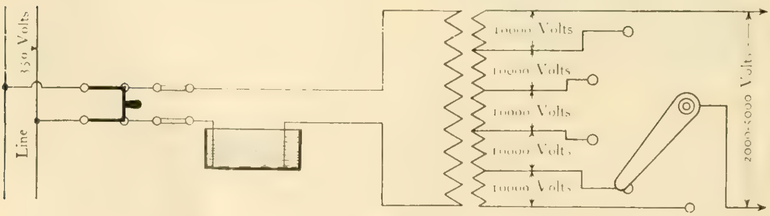


FIG. 7

Voltage regulation by means of water rheostat in series with low-tension winding. Range of variation, from approximately 25 per cent. to 100 per cent. of the maximum voltage of testing transformer. Suitable for general use, with exceptions noted in text. This diagram shows a further variation of the voltage by means of taps brought out from the high-tension winding of the testing transformer.

sumes that the generator and the testing transformer may be used as a unit. This method of variation gives a considerable range of

testing voltage, depending on the design of the generator, the amount of field resistance available, and the relative amount of charging current required in the test. This variation may usually

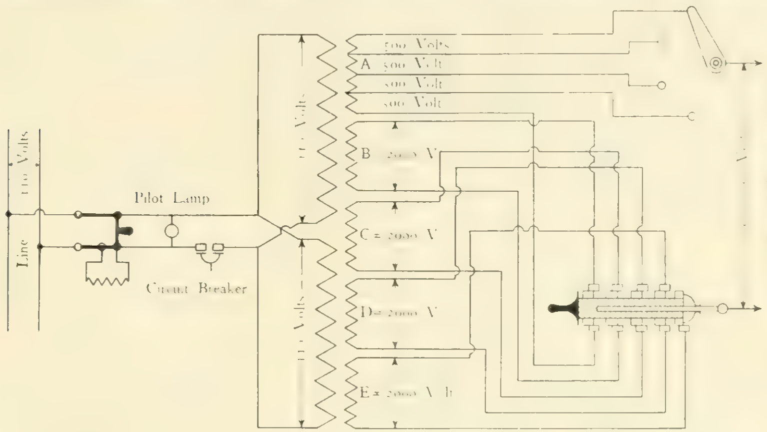


FIG. 8

Voltage regulation by steps in testing circuit. Circuit must be opened between steps. Coils not in use disconnected from testing circuit by special plug switch. Resistance in primary through which circuit is closed to prevent surges. Suitable for general low voltage testing.

be depended upon to be from 50 per cent of the normal rated voltage of the generator to a slight amount above the normal voltage. The variation of the testing voltage by the generator field is unsatisfac-

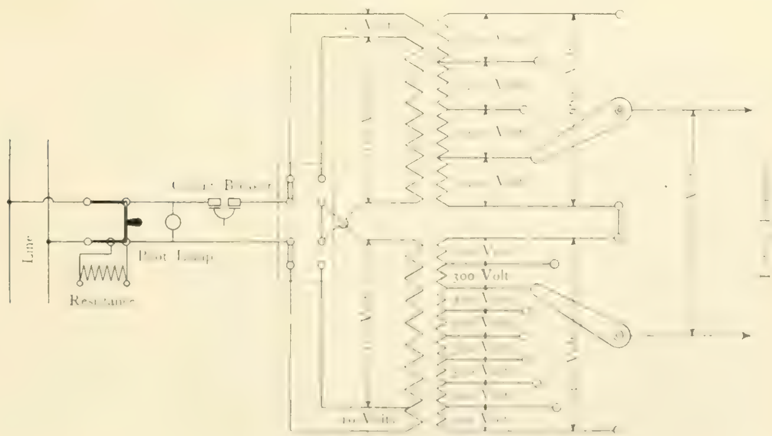


FIG. 9

Voltage regulation by steps in testing circuit. Circuit must be opened in passing from one step to another. Primary suitable for 100, 210 or 220-volt circuit. Range of voltage, from 2.5 per cent. of normal to normal voltage, by steps of 2.5 per cent. Suitable for general low voltage testing.

tory when the charging current is large and the field current very low, for the reason that the charging current passing through the armature reacts on the field and causes an unsteady condition of the voltage, which is very undesirable. With this exception, the variation of the field of the generator is the most satisfactory method that can be followed, within the limits given above. This general plan is shown diagrammatically in Figure 6.

(*b*) *By means of a resistance in series either with the primary or the secondary of the testing transformer.* This method assumes

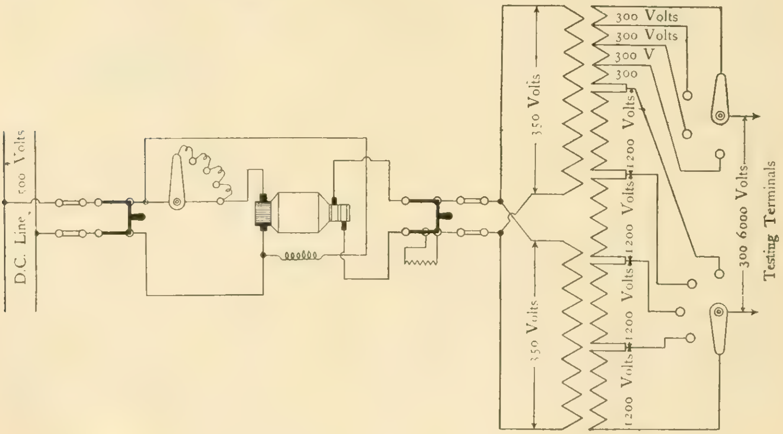


FIG. 10

Direct-current to alternating-current testing set. Direct-current to alternating-current or inverted rotary used to transform 500-volt direct current to 350-volt alternating. Voltage regulation by series resistance in direct-current circuit and by steps in testing circuit. Testing circuit must be opened between steps. Suitable only for small sizes and comparatively low voltage work.

that the source of supply is a constant-potential circuit. The type of resistance most frequently used consists of a water rheostat of some form, although any convenient resistance can of course be used. For small testing capacities this method is quite satisfactory, particularly if means are at hand for measuring the testing voltage in the high-tension circuit. For large capacities, the resistance becomes either very large if used in the primary, or very difficult to build and insulate if used in the secondary. Water resistance must be of such capacity that there will be comparatively little formation of gas on the resistance plates, as this formation may cause intermittent variations of the resistance and consequent undesirable variations in the testing circuit. This requires a large capacity

water rheostat. The principal advantage of this method of control is its cheapness. Its disadvantages are the large size of water rhe-

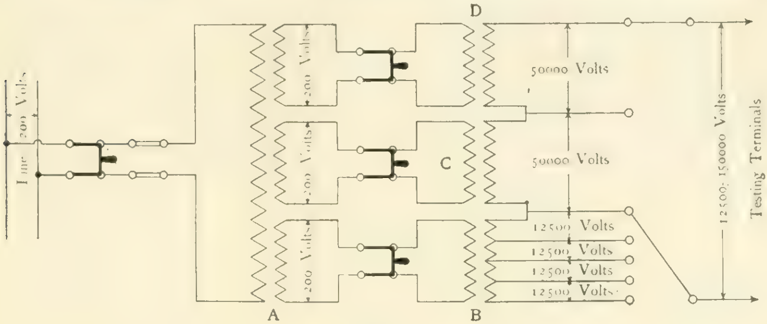


FIG. 11

Voltage regulation by steps in testing circuit. Testing transformer in series with insulating transformer in primary to add insulation to system. Output may be increased on the lower voltages by connecting high-tension windings in multiple. Suitable for use with transformers whose individual insulation is not sufficient for the final testing voltage. Insulating transformer requires high insulation between all coils.

ostat required, the intermittent variation of voltage apparently due to the formation of gas from the decomposition of the water, the change of the e.m.f. wave to a more peaked form, and variation

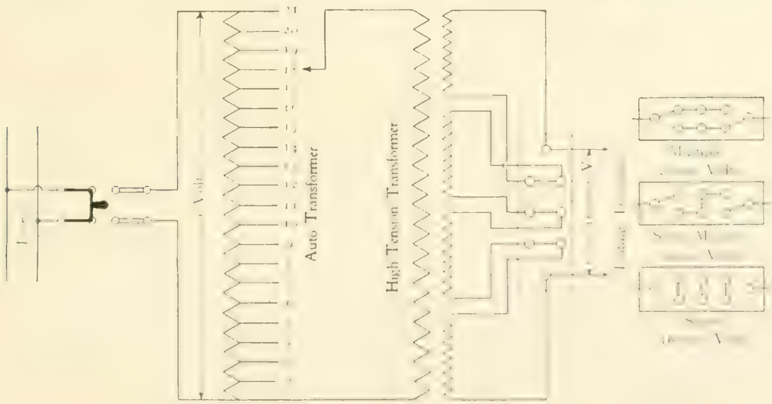


FIG. 12

Voltage regulation by regulating transformer and dial, also by combinations of coils in high-tension winding. Range, 5 per cent. steps from 5 per cent. to 100 per cent. of normal voltage without opening the circuit. Suitable for all classes of work and with testing transformers up to 25-kw or 30-kw capacity.

of the voltage due to the change of resistance as the water becomes heated and evaporates.

For general plan see diagram, Fig. 7, where a water rheo-

stat is shown in the primary circuit of the transformer, with a further variation by taps in the high-tension winding.

In general, the writer has found this method far less satisfactory than the method about to be described.

(*c*) *Variation by steps.* A very considerable range of testing voltage may be obtained by bringing out loops from the high-tension side of the testing transformer, with further combinations of the low-tension windings. This plan requires that the testing

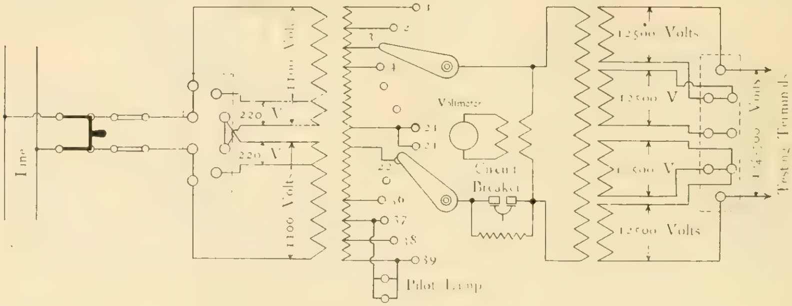


FIG. 13

Voltage regulation by regulating transformer and by combinations of coils in high-tension windings. Two dials, arranged, one to give 0.5 per cent. steps and the other 5 per cent. steps without opening the circuit. Intermediate circuit may be grounded for safety to operator. Suitable for all voltages and all capacities up to 200-kilowatt.

circuit be broken from step to step. Figs. 8, 9, 10 and Fig. 1, show such arrangements suitable for low-voltage testing.

Very close regulation of the testing voltage may be obtained by the use of a second transformer, which may be called a regulating transformer. The regulating transformer is connected direct to the line and has a large number of loops in its secondary winding, which are connected through suitable dials to the primary of the testing transformer. This transformer may be wound with a primary and secondary, or may be of the auto type. A single dial arrangement is shown diagrammatically in Figure 12, and a photograph of a 25-kw auto-regulating transformer with dial is shown in Figure 2. A double dial arrangement, giving still further refinement as to the gradation of the voltage, is shown diagrammatically in Figure 13.

Figure 3 shows photograph of a portable double dial set of 30-kw capacity at 30 000 volts, complete with switch, fuses, circuit-breaker, choke coil for burning out faults, etc. With this ar-

rangement it is customary to make the total range of the small step dial equal to two steps of the main dial. For quick adjustments the small step dial may be set at its middle point and the test voltage set approximately by the large step dial, final close adjustment being obtained by the small step dial. With twenty points in each dial, steps of 0.5 per cent are obtainable over the whole range from 0 to 100 per cent. A feature of this scheme that may be objectionable in the most exacting work lies in the fact that the small step dial must be returned to the zero point for each large step when changing the voltage over a wide range by small steps, or there will be a succession of small and large steps. This difficulty may be entirely overcome by the use of a third, or auxiliary, regulating transformer, as shown in Figure 14. An inspection of this diagram shows that

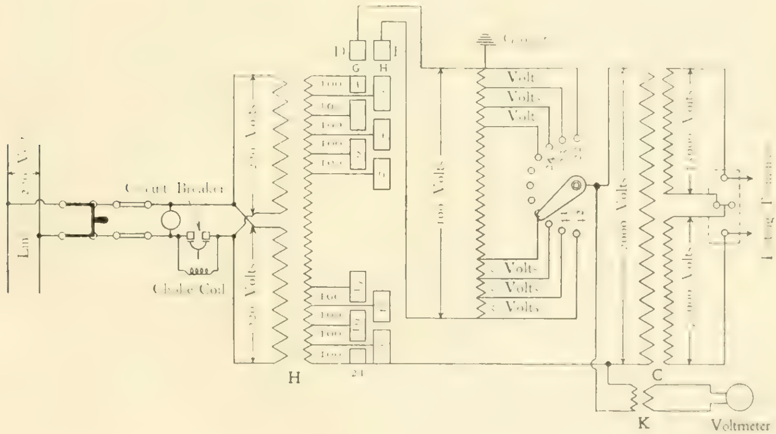


FIG. 14

Voltage regulation by regulating and auxiliary regulating transformers, with double dial. Range, steps of .025 per cent. to 100 per cent. without opening the circuit. Full equipment of instruments, means for locating faults, etc. This makes an outfit suitable for universal application for sizes up to 250 kilowatts and for any maximum voltage which may be required.

it is in effect the same as the double dial arrangement with the exception that provision is made for connecting the small auxiliary regulating transformer across any consecutive pair of taps in the main regulating transformer and then varying the voltage across this pair of taps by very small gradations.

As the direction of the current is reversed in the auxiliary transformer with each large step, a continuous increase or decrease in the voltage of the testing transformer by the smallest steps with-

out opening the circuit may be effected by moving the auxiliary dial over full range, then moving the main dial one step, then reversing the auxiliary dial over full range, etc. Twenty points on each dial give steps of one-fourth of one per cent. from 0 to 100 per cent without opening the circuit. Figure 4 shows complete regulating transformer with oil-insulated dials, instruments, etc., and Figure 5 a 200-kw, 150 000 volt-testing transformer used in connection with this regulating set.

A still further variation of the voltage may be obtained in most transformers by providing a symmetrical arrangement of the high-tension windings, which may be connected in multiple, multiple-series, or series. Four equal combinations will give three voltages at which the transformer may be used at its full rated capacity, these being 25 per cent, 50 per cent and 100 per cent of the maximum rated voltage.

(TO BE CONTINUED.)

SOME POINTS ABOUT THE INDUCTION MOTOR

THE EFFECT OF VARIATION IN THE SUPPLY CIRCUIT

J. W. WELSH

SLIP.—The synchronous speed of an induction motor is the number of alternations per minute of the current in the supply circuit, divided by the number of poles of the motor, and is the limiting speed at which the motor tends to run as the load and the various losses are decreased toward zero.

The difference between this speed and the actual speed of the motor at any given load is termed the slip. This is generally expressed in per cent. of the synchronous speed.

The slip varies approximately as the inverse square of the applied e.m.f. If the synchronous speed of a certain motor is 1000 r.p.m. and the slip at a given torque is four per cent. the motor speed will be 960 r.p.m. If now the voltage be doubled and the

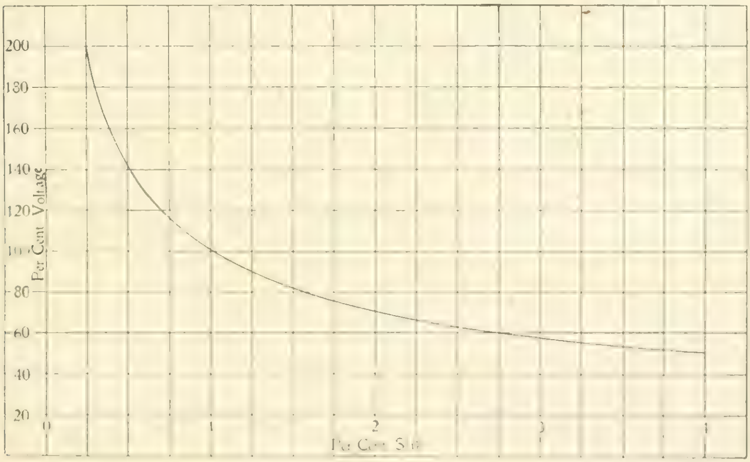


FIG. 1

torque held constant, the per cent. slip will be reduced to one-fourth of its former value or one per cent., and the corresponding speed will be 990 r.p.m. If one-half of the normal voltage be applied the slip will be increased to sixteen per cent. and the corresponding speed will be 840 r.p.m. with the same torque delivered.

This relation is shown by the curve in Fig. 1 where a slip of one per cent. is assumed at an applied voltage of 100 per cent. From

this it is clear that greater relative changes in speed occur when the voltage is below normal than when it is above normal.

As seen in the table below, small increases in the voltage are accompanied by a corresponding decrease in the slip. Small decreases in the voltage are accompanied by twice as great an increase in the slip. This table is for a normal slip of one per cent. at 100 per cent. voltage. For any other normal slip the values in the table are proportionate.

Per cent. voltage applied	Approximate per cent. slip
80	1.5
90	1.25
100	1.0
110	.8
120	.7
130	.6
140	.5

The slip is directly proportional to the resistance of the secondary winding. In the squirrel cage, or short-circuited type of secondary the resistance necessary for the desired slip is accomplished in the design of the secondary. By different combinations of cross-section and conductivity of the end-rings a wide range of full-load speed may be obtained on motors that in all other respects are exactly similar.

In cases of wound secondaries where an external resistance is employed any slip from 100 per cent. to a minimum determined by the lowest possible resistance (secondary short-circuited) can be obtained.

Torque—The torque developed by a motor varies as the square of the applied e.m.f. This is approximately true whether the motor is at rest or running.

As a rule the starting torque with the short-circuited type of motor secondary is equal to one and one-half or two times the full load torque on full voltage, or it is equal to the full-load torque with 82 to 71 per cent. of full voltage.

The pull-out or maximum torque which the motor can develop on full voltage is commonly two to three times its full-load torque. In particular cases it may be more or less.

Roughly the torque is proportional to the inverse square of the frequency; therefore a decrease in the frequency will increase the maximum torque developed by the motor.

The maximum torque of a given motor is a constant, within

certain limits, irrespective of the slip. This maximum torque can therefore be obtained at any desired slip by suitable design.*

Motors with high resistance secondaries do not pull-out, since the maximum torque is not reached until the motor stops. Such motors are designed for service where heavy loads must be started from rest as in crane and elevator service.

To determine the torque which a motor of a given horse power will develop, multiply the horse power by the constant 5250 and divide by the revolutions per minute.†

FREQUENCY—If a motor is run at another frequency than that for which it was designed, the voltage may be changed in the same proportion. Consider the case of a two-phase-200 volt 25 cycle motor. It can be operated efficiently to its full capacity on a 50 cycle circuit if the voltage is increased to 400 volts. By doing this the iron is worked at the same flux density, since the flux is proportional to the e.m.f. divided by the frequency, and accordingly the flux remains constant with this simultaneous rise in e.m.f. and frequency.

Other things being equal the torque is proportional to the product of the flux through the secondary, and secondary current. The secondary current depends on the flux and secondary frequency, so that, having the same flux, to develop the same torque in both cases, the secondary frequencies must be the same, *i. e.*, the actual slip in r.p.m. must be the same. The per cent. of slip will of course be half at the higher frequency. Under these abnormal conditions the motor develops twice the horse-power at approximately twice the speed.

The results of an actual test on a 30-hp., two-phase, 400 volt, eight-pole, 60-cycle motor run on 60 and 25.8 cycles are:

Frequency	Volts	Amp.	Real Watts	Torque	r.p.m.	Slip in r.p.m.	Real Efficiency	Power Factor	Horse Power
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25.8	[illegible]	[illegible]	12000	[illegible]	[illegible]	55	[illegible]	[illegible]	[illegible]

The torque was held at 185 pounds in both cases, and the voltage applied in the second case was 25.8/60 of 400=170 approximately.

In order to develop the same horse-power when a motor is not

*See "The Polyphase Induction Motor." B. G. Lamme, *The Electric Club Journal,* Vol. I, p. 431; Fig. 6, p. 442.

†See "Factory Testing of Electrical Machinery."—R. E. Workman, *The Electric Club Journal,* Vol. I, p. 424.—5250 is the reciprocal of 0.000 1904.

run at its designed frequency, the voltage should be changed in proportion to the square-root of the frequency. For example a 200 volt 25 cycle motor may be operated on a 50 cycle circuit with approximately the same performance if the voltage is increased to 283. In this case the torque has one-half its normal value and the motor runs at double speed. The per cent. slip is less since but one-half the torque is developed and the starting torque is less since the voltage is not increased in proportion with the frequency.

There is little difference in the size and weight of two induction motors of the same output, one designed to run on 25 cycles and the other on 60 cycles when both are to run at the same speed. Obviously the 60 cycle motor will have twice the number of poles and the pitch of its coils will be approximately one-half.

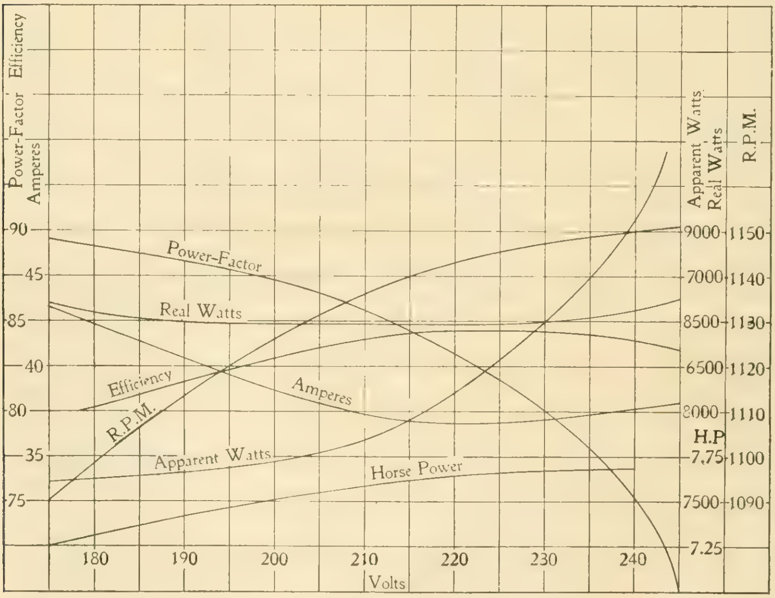


FIG. 2—PERFORMANCE OF AN INDUCTION MOTOR AT CONSTANT TORQUE

Voltage—The performance of a motor at constant torque on various voltages is illustrated in Fig. 2. These curves were taken by brake test on a motor with squirrel-cage type of secondary. This motor runs normally at a point on the saturation curve rather high as compared to the usual induction motor.

Current—The full-load current of an induction motor may be approximated by allowing an input of 10 amperes per horse power

per 100 volts. This is known as the total current, and applies to a single-phase machine. To find the current per lead this value should be divided by 1.73 for a three-phase machine and by 2.0 for a two-phase machine.

The no-load current is about one-third or one-fourth the full-load current. In crane motors and in single-phase induction motors the proportion is higher.

On no-load the current and watts increase with a decrease in frequency. This is noticeable though the variation is only a few per cent.

EFFICIENCY—The efficiency of a motor is sometimes roughly taken as equal to the ratio of the actual to the synchronous speed. It can never be greater than this, as the one represents the rate at which energy is supplied, and the other, that at which it is delivered. An increase in efficiency occurs with an increase in voltage. Changes in frequency which do not exceed a few per cent. have little effect on the efficiency.

POWER-FACTOR—The power-factor decreases with a rise in voltage, and the change is quite marked as the iron approaches saturation. For the same torque, the power-factor is unaffected by a change in frequency if accompanied by a corresponding change in voltage. This is seen to be true, since the primary and secondary flux remain the same, and consequently the magnetic leakage is the same. For the same voltage and with the same torque developed by the motor, variations in frequency of five per cent. or more have little influence on the power-factor.

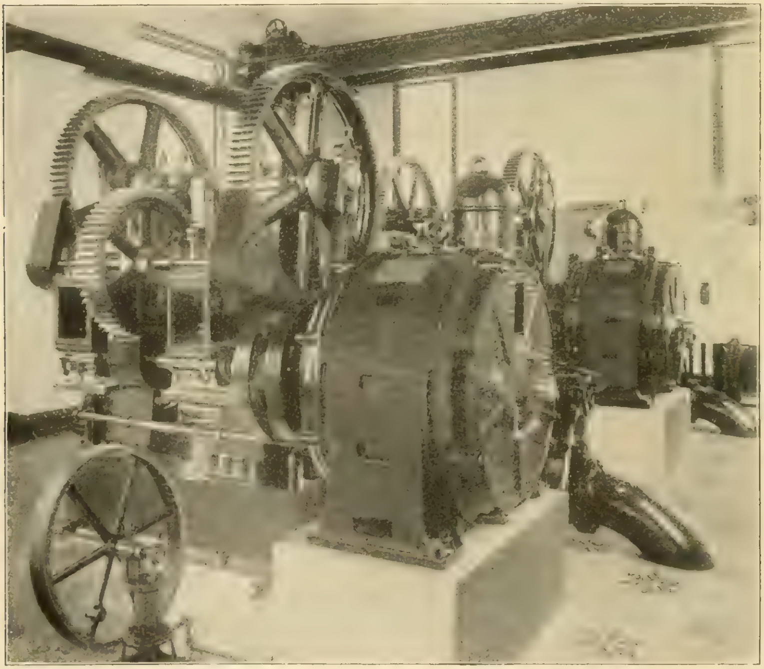
PHASE—A two or three-phase machine will run on one phase after being started. The maximum torque is about 35 or 40 per cent. of the normal maximum torque.

WOUND SECONDARY—An induction motor with a wound secondary has among others the following peculiarities. With one leg of the three-phase secondary winding open it pulls in at half speed, and continues to run at the same rate. This does not affect the balancing of the current in the primary phases. If the open leg is closed the motor will come up to full speed. Opening one leg again will not cut the speed in two unless the load is too great, in which case the motor will pull-out. The pull-out in this case has the same value as with one leg of the primary open, (secondary all closed) about 40 per cent. of normal pull-out.

ELECTRIC MOTOR APPLICATIONS*

J. HENRY KLINCK

EXPERIENCE has shown that it is necessary to make a thorough investigation of the characteristics of the driven machine before making any recommendations as to the type of motor and motor control to be used. A motor is a prime mover just as much as is a steam, gas, water, or air engine; and it is recognized that each of these gen-



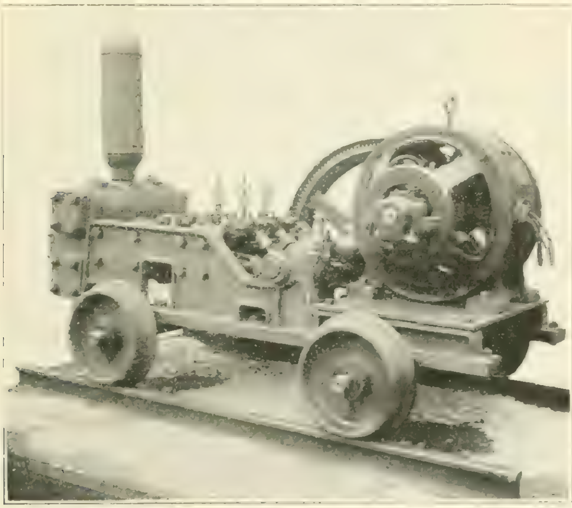
ALLEGHENY CITY PUMPING STATION, SHOWING GOULD'S TRIPLEX PLUNGER PUMPS DRIVEN BY INDUCTION MOTORS, THROUGH DOUBLE REDUCTION GEARING

eral types requires modifications in accordance with operating conditions. There is no reason why a motor equipment cannot be made which will meet a given set of requirements, but it is useless to expect this particular equipment to answer all requirements. This is becoming recognized more and more, and, in consequence, the field of motor application is continually extending.

*Read before the Ohio Electric Light Association, Put-in-Bay, Ohio, August 16-18, 1905.

An electric motor, working under load, may have its speed varied in either of two ways: First by change in the voltage impressed on the armature terminals; second, by change in the field strength. Theoretically, either of these two methods will produce any desired amount of change; within the limits set by practice, however, it is found that, in order to obtain satisfactory results, it is necessary that an exact knowledge of the work to be accomplished be obtained.

Under the conditions of a constant potential, two-wire circuit the usual method of varying the voltage at the armature terminals

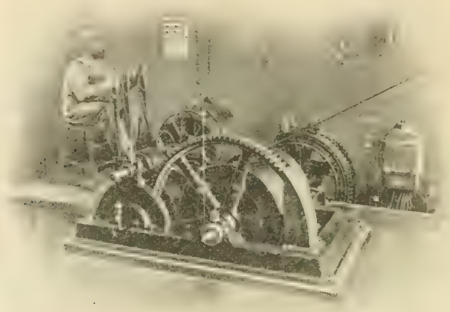


ALLENTOWN TRIPLEX PLUNGER MINE PUMP, MOUNTED ON TRUCK, DRIVEN BY TYPE S MOTOR, THROUGH SINGLE REDUCTION GEARING

is by means of the insertion of an external resistance in the armature circuit. A change in the field strength is accomplished by the placing of a rheostat in the field circuit. These two methods give speed changes having the following characteristics: Speed variation, obtained by the insertion of resistance in the armature circuit, will render available speeds *below* the normal speed of the motor. Speed changes, obtained by variation in the field strength, will render available speeds *above* the normal speed of the motor. The term, "normal speed," is used as meaning the speed at which a shunt, or compound, motor will run when connected directly to

the line, no resistance being used either in armature or field circuit, and full load output being demanded of the motor.

The work required of a variable speed motor may have either or both of two distinctive characteristics: It may require constant torque, or constant output. It is somewhat difficult to draw a dividing line between these two classes, but an approximate division would show, printing presses, positive blowers, plunger



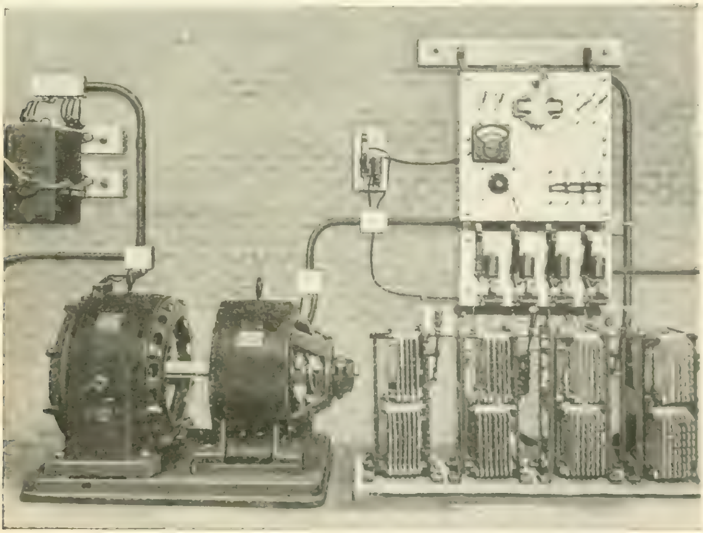
MINE-HOIST DRIVEN BY INDUCTION MOTOR, HOIST OPERATION CONTROLLED BY MEANS OF LEVERS OPERATING FRICTION CLUTCH AND HAND BRAKE

pumps, conveyors, hoists, etc., as instances in which constant torque is demanded; this, however, does not consider the starting conditions which, especially in the case of printing presses and hoists, require a torque considerably in excess of the normal. When the characteristics of the driven machine are such that constant torque is demanded of the motor and the variation in speed is obtained by means of armature resistance control, the field strength remaining constant, the current in the armature remains constant and the output of the motor varies directly with the speed. When, with driven machines having similar characteristics, the constant torque required is obtained from a motor whose speed is varied by means of field resistance control, the current in the armature circuit will not remain constant, but will change with each change in field strength, the output of the motor varying with the speed as before.

Since the torque is the result of reaction between the magnetic fields set up by the armature and field currents, the greatest torque will be available when these currents are a maximum. In an appli-

cation in which abnormal torque is required at starting, this will be obtained with a smaller armature current when field resistance control is used, because the field strength is a maximum at the low speeds. This does not indicate that this method is the best one to use under all conditions; it is of interest chiefly in connection with any installation in which continued operation at very low speeds, under constant torque conditions, is required.

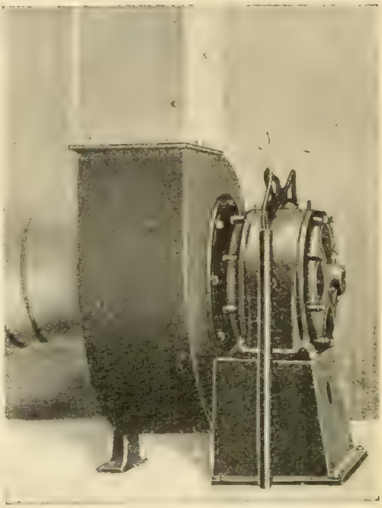
Applications of variable speed motors requiring constant output may be classed under the general head of machine tools, comprising all turning, cutting and grinding tools, and machines. A turning or grinding tool is one of which the work normally required is constant in amount and continuous in character, as lathes, boring mills, saws, drill presses, milling machines, etc. A



MOTOR INSTALLATION AT THE PRIVATE AUTOMOBILE GARAGE OF ACME TEA CO., PHILADELPHIA, PA., CONSISTING OF ALTERNATING-CURRENT INDUCTION MOTOR DRIVING DIRECT-CURRENT GENERATOR MOUNTED ON SAME BED PLATE.

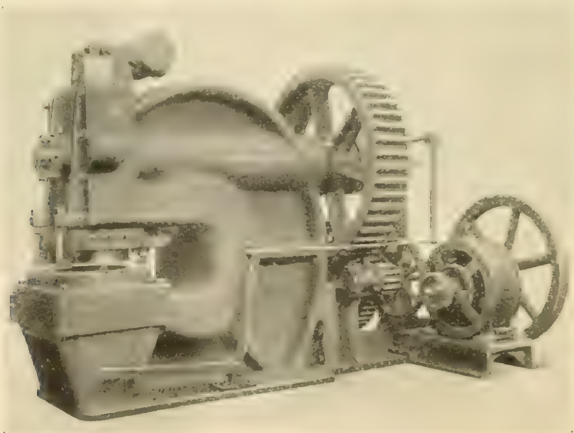
cutting tool is one of which the work required is intermittent in character and amount, as planers, shapers, slotters, presses, punches, etc., usually consisting of two operations, that of cutting proper and that of returning the work or tool for the next cut. Under particularly favorable circumstances, the average amount of work done in each portion of the cycle may be the same, but usually there

is a decided peak at the beginning of each forward or return stroke, that of the return being the maximum, the proper use of a fly-wheel being of material assistance in smoothing out the peaks.



INDUCTION MOTOR DIRECT-CONNECTED TO SHAVING EXHAUST FAN

When the characteristics of the driven machine are such that constant output will be required over a variable speed range, this can only be done satisfactorily by means of field resistance control. To make this clear, consider a motor driving a machine tool, the speed control being obtained by means of resistance inserted in the armature circuit. For a given amount of resistance the drop in voltage over that resistance will vary with the current in the resistance, causing a variation in the voltage impressed on the armature terminals, and consequently a change in speed of the armature. Assume the case of a machine

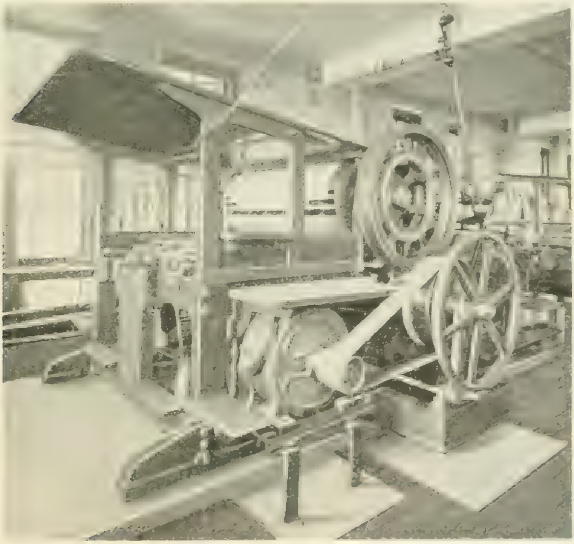


TYPE S MOTOR DRIVING CLEVELAND PUNCH, FLY WHEEL USED ON MOTOR SHAFT

tool taking a cut through material of irregular cross-section, the cut being first heavy, then light, at times the

tool not touching the work at all. This will cause wide fluctuations in the current through the armature circuit and resistance, and consequently wide fluctuations in the voltage impressed on the armature circuit, due to the varying currents in the controlling resistance. It is absolutely impossible to obtain a fixed speed with this method of control should the working conditions be those obtaining in practice. In this case we have a machine theoretically demanding constant output; practically this requirement is changed by the conditions of operation.

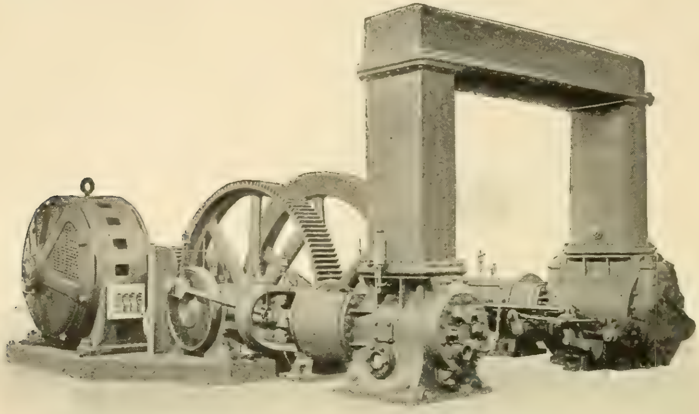
When constant output is required by the driven machine and



PRINTING PRESS DRIVEN BY TYPE S MOTOR, DIRECT GEARED

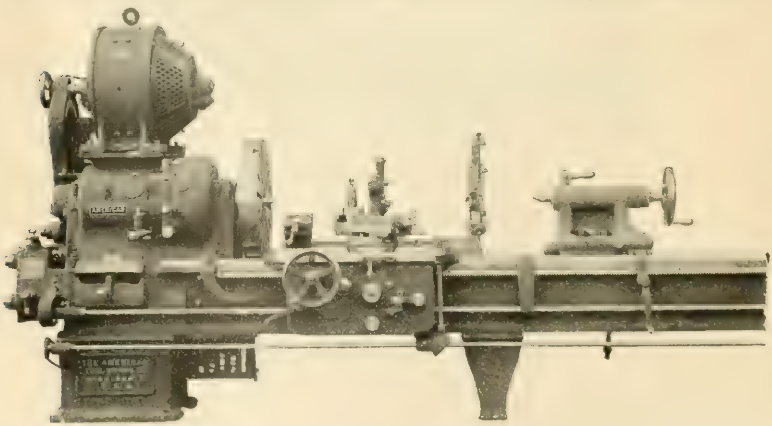
speed variation is obtained by means of field resistance control, the current in the armature remains constant, independent of the speed. This condition best fulfills the conditions generally met with in motor installations for the driving of machine tools, and it it due to a misunderstanding of the fundamental requirements involved that we have seen within the last few years many changes in the so-called variable speed systems. It should be borne in mind that the variation of the speed of a motor in itself is a very simple matter: almost any motor can be taken and its speed varied within limits which are set only by the mechanical characteristics of the construction of the motor. When, however, it is desired to vary

the speed conditions obtaining in practice, that is, when the motor is doing *useful* work, the matter is not so easy from an operating



200 H. P. INDUCTION MOTOR DIRECT CONNECTED TO A RAND AIR COMPRESSOR DIRECT GEARED

standpoint. In this case there are many considerations which govern, among others; the motor must not be too large, and its speed, varying over a considerable range, must not be too high at its upper limit; here are two factors between which a compromise must be

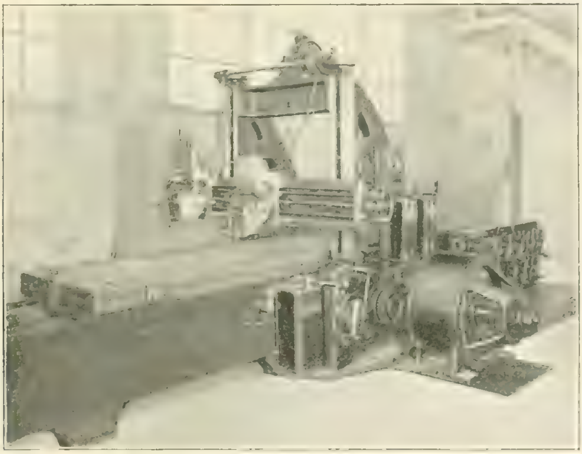


TYPE S MOTOR DRIVING AMERICAN TOOL WORKS CO.'S LATHE, DIRECT GEARED. MOTOR CONTROLLED FROM LATHE CARRIAGE

arranged at the outset. Making the maximum speed limit low increases the size of the motor, and consequently its cost. Increasing

the speed limit decreases the size and cost of the motor, but increases the mechanical difficulties, and also, under certain conditions, makes commutation unsatisfactory.

Consider a motor running at full load, and also consider that constant output is demanded of it, as would be the case were it direct connected to an engine lathe; assume that it is desired to increase the speed in the ratio of 4 to 1. Since the output is equal to the counter e.m.f. of the motor multiplied by the current in the armature, and since in addition the counter e.m.f. depends upon the product of the speed and field strength, if we decrease the field strength sufficiently to raise the speed to four times its normal

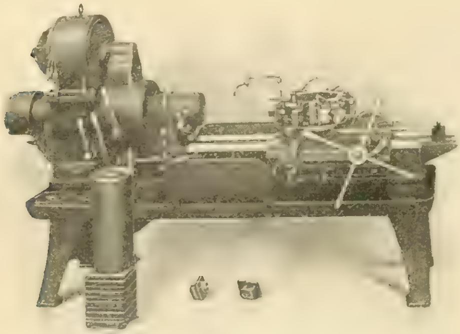


TYPE S MOTOR DRIVING PLANER ELECTRIC CONTROLLER-SUPPLY CO.'S SYSTEM IN WHICH THE MOTOR IS REVERSED AT EACH STROKE OF THE PLANER BED

value, we have apparently the same operative condition existing as before; unfortunately, this is not so in practice. The difficulties may be briefly stated as follows:

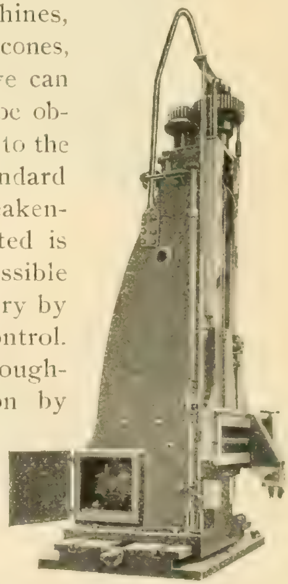
A certain peripheral armature speed has been recognized as most desirable, all conditions being taken into consideration. This difficulty is capable of being handled satisfactorily by somewhat decreasing the normal speed. The chief difficulty, however, lies in the commutation. To secure satisfactory commutation it is necessary that commutation take place in a field having a certain definite value, this value being sufficient to insure a reversal of the current in the armature coils while the commutator bars are under

the brushes. Should this not be done, destructive sparking will occur. This sparking is not necessarily of a visible nature; it may begin and end while the bar is under the brush, and it is usually to this that the unexplained roughing up and destruction of apparently sparkless commutators is due.



TYPE S MOTOR DRIVING HOLLOW HEXAGON LATHE OF THE WARNER & SWASEY CO.; CONTROLLER SHOWN MOUNTED SEPARATELY

Securing an increased speed by means of field weakening impairs the value of the field for the commutating purpose. In a standard motor it is, as a general rule, possible to obtain a speed variation amounting to 25 per cent. by means of field variations. In many cases this can safely be increased to 50 per cent. When we stop to consider that the variation betwen cones in machines, driven by means of countershaft and speed cones, is usually from 30 per cent. to 50 per cent., we can easily obtain such speed variation as may be obtained from shifting the belt from one cone to the next adjacent one, by means of a standard motor and the use of a rheostat for weakening the field. If the motor frame selected is of a size sufficiently large, it is usually possible to obtain all the speed variations necessary by means of the use of field resistance control. The efficiency is practically constant throughout the entire range of speed variation by means of field resistance control.

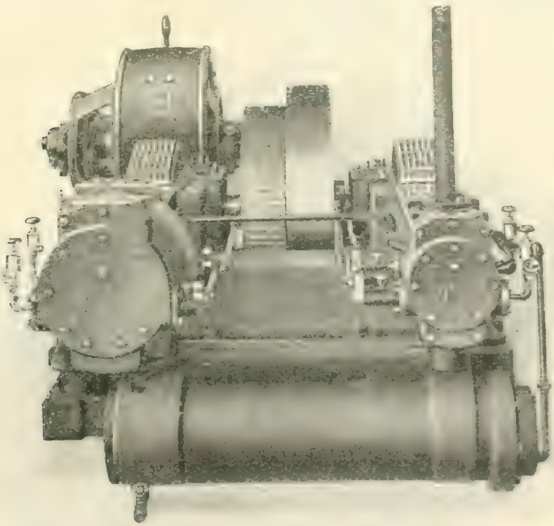


PORTABLE SLOTTER DRIVEN BY INDUCTION MOTOR ENTIRELY ENCLOSED IN FRAME OF TOOL

In the variation of speed by means of armature resistance control, this is not true by any means. The resistance being placed in the armature circuit, the current through the armature and resistance is exactly the same. If the speed of the armature is below normal,

we know that a portion of the energy liberated in the circuit, including the armature and resistance, is used in the armature itself, another portion being wasted as heat in the resistance, and as the speed is decreased, this proportion of wasted to useful energy increases, until when the speed is brought down to zero, all the energy supplied by the circuit is dissipated in C^2R losses, most of them occurring in the resistance. With a motor controlled as above, and operating under conditions of constant torque, requiring the same current in the armature, no matter what the speed, the efficiency will be very low and will vary directly with the speed.

Armature control is perfectly satisfactory under certain condi-

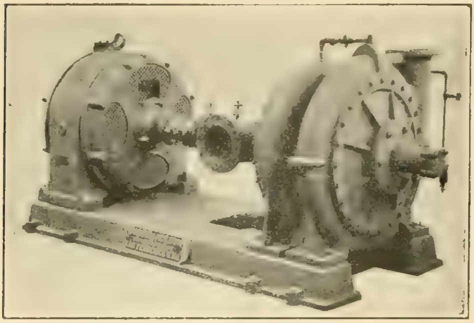


RAND DRILL DOUBLE AIR COMPRESSOR DRIVEN BY TYPE S MOTOR

tions, as with a whip hoist driven by a series motor, the service conditions requiring constant starting, stopping and reversing.

A combination of these methods can also be used to advantage in the case of a fan which is used for ventilating purposes. The volume of air delivered by a fan varies approximately as the speed of the fan. The pressure at which the air is delivered varies approximately as the square of the speed. Consequently the power required of the motor will vary approximately as the cube of the speed of the fan. Under these conditions, if the speed of the fan is decreased, the current required by the motor will decrease ap-

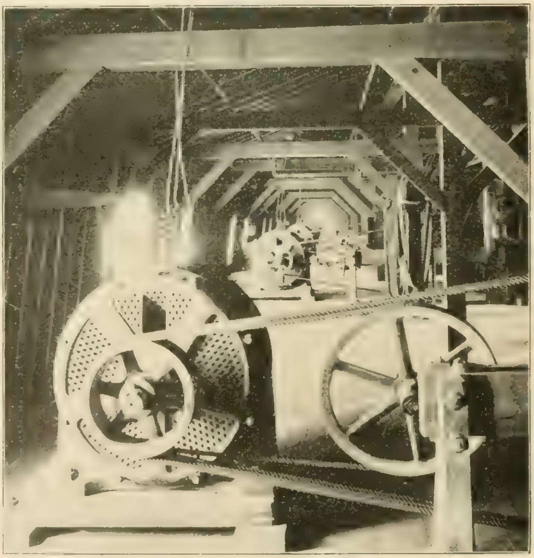
proximately as the cube of the speed, and consequently, at low speeds, the losses in the regulating resistance will not be of any considerable amount. The most efficient method of control from a commercial standpoint in this particular case would be shunt field resistance, combined with resistance in the armature circuit for the lower speeds.



BYRON JACKSON TWO-STAGE CENTRIFUGAL PUMP, DRIVEN BY INDUCTION MOTOR, RAISING WATER 300 FEET; DIRECT CONNECTED

This method of control is particularly useful for the operating of printing presses, for in this class of work the press demands an abnormal torque while starting and at the very lowest speeds, the operation of printing proper being done at the higher speeds.

The present commercial methods of varying the speed of induction motors give results similar to those obtained with the use of resistance in the armature circuit of direct current motors, and consequently constant speed is never obtained except under conditions of an absolutely constant load. These methods consist in varying the voltage impressed on the primary winding either by the use of resistance, transformers, or auto-starters, or by varying the current in the

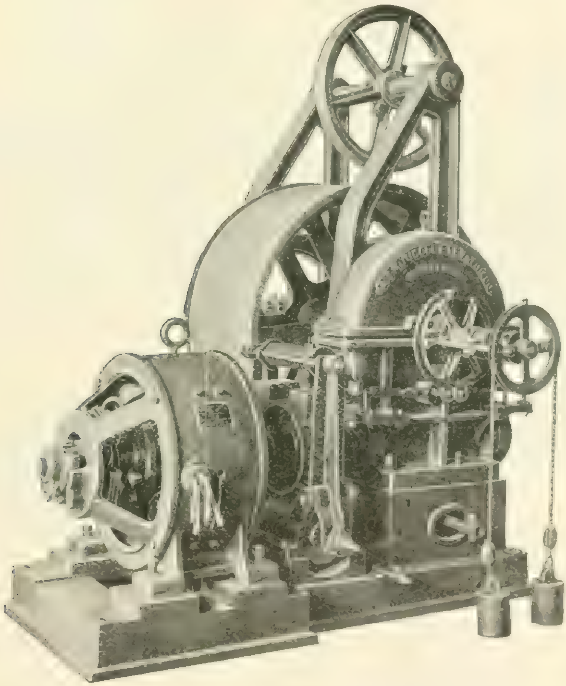


INDUCTION MOTORS FURNISHING POWER THROUGH ROPE DRIVE

secondary winding by the insertion of resistance in this winding.

There are other methods which are of use in particular cases, for instance, the primary windings may be so arranged as to halve the number of poles giving double normal speed when desired. This arrangement being frequently used for the control of pumps, although open to some criticism from an operating standpoint.

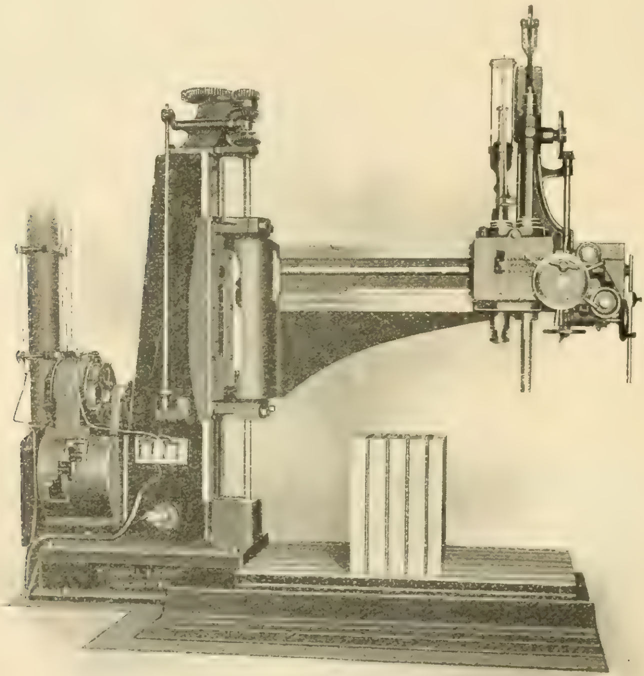
The single-phase alternating-current commutator type of motor has characteristics exactly similar to those of the direct-current



TYPE S MOTOR DRIVING J. M. NICOLL CO.'S ELEVATOR HOIST. CONNECTION BETWEEN MOTOR AND MECHANISM THROUGH WORM GEARING

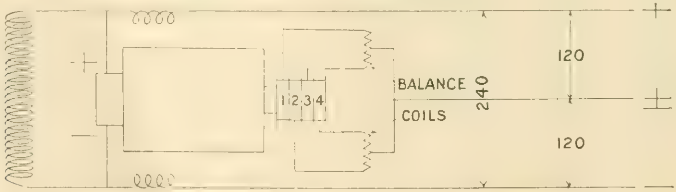
series motor. It is controlled by varying the voltage impressed on the armature terminals, either by the insertion of resistance directly in the circuit, or by the use of transformers, or autostarters. At present this motor is used more particularly for single-phase electric traction on circuits of 3 000 alternations, but it is in commerical operation on 7 200 alternation circuits as well. This motor will take the place of the direct-current series motor for all work which that

motor is now doing. Equipments now in service on various traction lines have demonstrated that there is no destructive sparking at the brushes. There is no danger of "flashing over;" this has



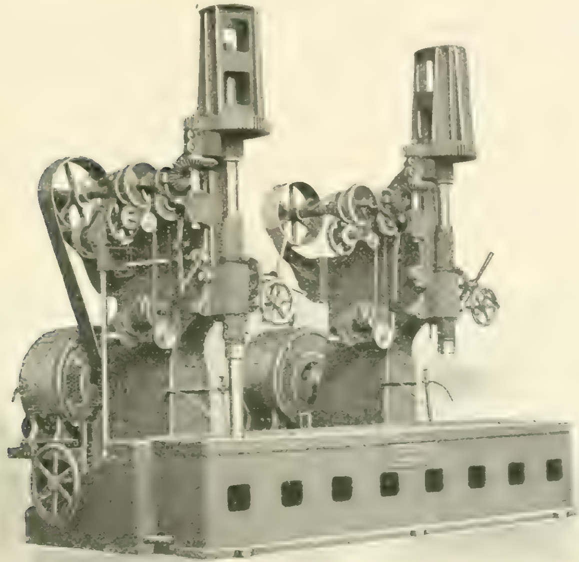
RADIAL ARM DRILL DRIVEN BY INDUCTION MOTOR. SPEED VARIATION OBTAINED BY MEANS OF MECHANICAL SPEED CHANGER ON WHICH MOTOR IS MOUNTED

been satisfactorily demonstrated by tests which have been made on the 135-ton single-phase locomotive recently put into service by the



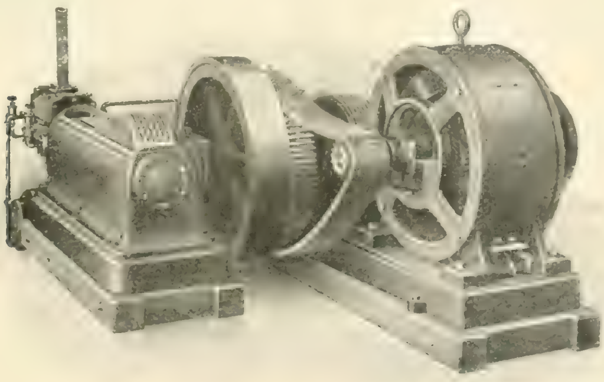
CONNECTIONS FOR THREE-WIRE VOLTAGE SYSTEM

Westinghouse Electric & Manufacturing Co. at their East Pittsburg shops.



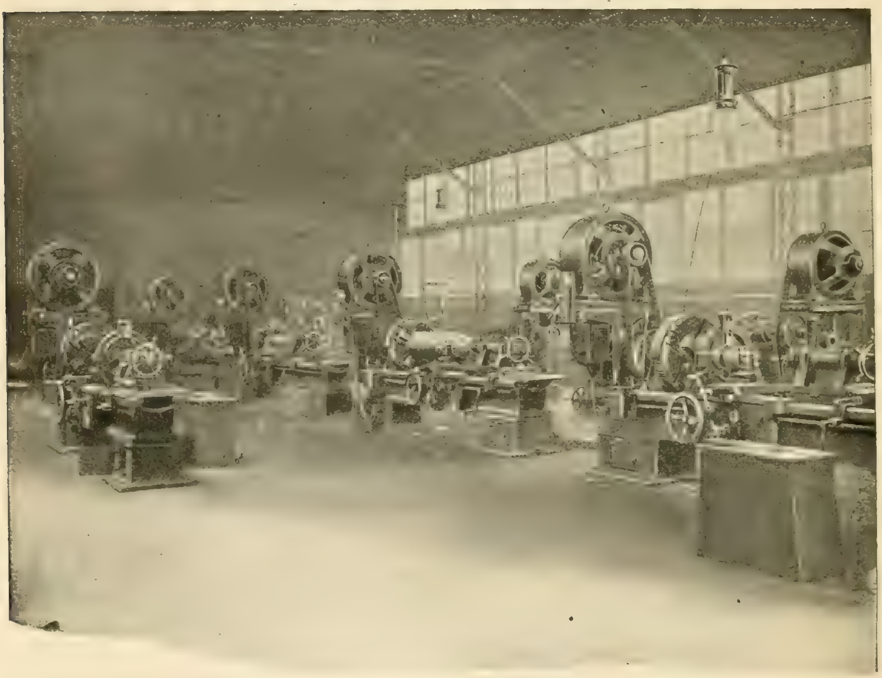
DOUBLE SPINDLE ROD BORING MACHINE, MADE BY BAKER BROS., TOLEDO, OHIO. DRIVEN BY TYPE S MOTORS. EACH HEAD DRIVEN BY DIRECT BELTED MOTOR

The service performed by an elevator motor may be taken as typical of one of the many cases in which the application of motors for industrial work is entirely special. The conditions under which



RAND DRILL AIR COMPRESSOR DRIVEN BY TYPE S MOTOR

these motors operate demand that the motor be started with as rapid an acceleration and as small consumption of current as possible. They also demand that the load be varied over quite a wide range with constant speed. The former of these conditions demands a series winding, the latter a shunt winding, and the successful elevator motor contains a combination of these two windings. At the time of starting, the motor is started with the shunt fields directly across the line, the series fields and the starting resistance in series



TYPE S A MOTOR DRIVING PUTNAM LATHES. CONTROLLER MOUNTED ON HEAD OF LATHE

with the armature. As the load is picked up, the starting resistance and series fields are cut out until the motor is running across the line as a simple shunt motor. It has been found that this combination of control gives an elevator motor with characteristics best suited to the general run of elevator work. There are certain elevator installations which require treatment peculiar to the conditions which surround them. These must, of necessity, be treated as special problems.

The three-wire balanced voltage system of distribution lends itself readily to the needs of those desiring to use variable speed motors. By using a three-wire balanced voltage generator, it is possible to use 120 volts to supply the light circuits, which may be either arc or incandescent lamps, and 120 and 240 volts for the motor circuits, the motor operating at the higher speeds on the 240 volt circuit and lower speeds on the 120 volt circuits. By using a motor with a two-to-one speed variation on a single voltage circuit, this arrangement gives a motor with a range of four-to-one on the three-wire balanced voltage circuit. The motor itself not being any larger than one for a two-to-one speed variation on the lower voltage when full output is required of it over the entire speed range. By properly connecting lights and motors, the whole light and power load is practically handled by a 240 volt distribution system, with the resultant economy in copper.

In installations where the three-wire system is not in use, or where it is not desired to install it, due to the limited lighting load necessary, it is possible to obtain any desired speed of variation by the selection of motors of proper design.

HOW TO START ROTARY CONVERTERS*

ARTHUR WAGNER

Case VII.

One three-phase rotary converter, operating from direct-current to alternating current with directed-connected exciter generator is started as follows:

(1) Open all circuit breakers and switches; cut in all resistances on the exciter rheostat; cut out all the resistance in the bus-bar rheostat, so that the converter may have full field for starting as a motor.

(2) Throw the transfer switch (6) in the lower position and then close the direct-current circuit breaker, thus connecting the shunt field of the converter to the bus-bars. Put the differential voltmeter plug in the four-point receptacle, indicating the full voltage of the direct-current bus-bars.

(3) Close the negative switch (4).

(4) Start the converter by gradually cutting out the resistance in the starting rheostat.

(5) When the machine is up to full speed the direct current ammeter will indicate a minimum current; close the positive switch and return the starting rheostat handle to its initial off position.

(6) Gradually build up the exciter voltage by cutting out resistance on the exciter rheostat. When the differential voltmeter points to zero, thus indicating that the exciter voltage equals the voltage on the converter field, throw the transfer switch in the upper position. The converter field is now excited from the direct-connnected exciter generator.

(7) Put the alternating-current voltmeter plug in any position in the eight point voltmeter receptacle. By putting the plug in the top position the voltmeter indicates the voltage across b-c; in the middle position a-c; bottom position a-b. Inverted rotary converters often possess a mixed load of lights and motors, causing unbalanced load conditions. For this reason the eight point voltmeter receptacle is usually desired in order that the voltage across any two lines may be read. The current in any line may be read by use of the ammeter plug switches as explained in Case V, No. 8 of this series.

(8) Close the alternating-current oil circuit breaker and the alternating-current switches.

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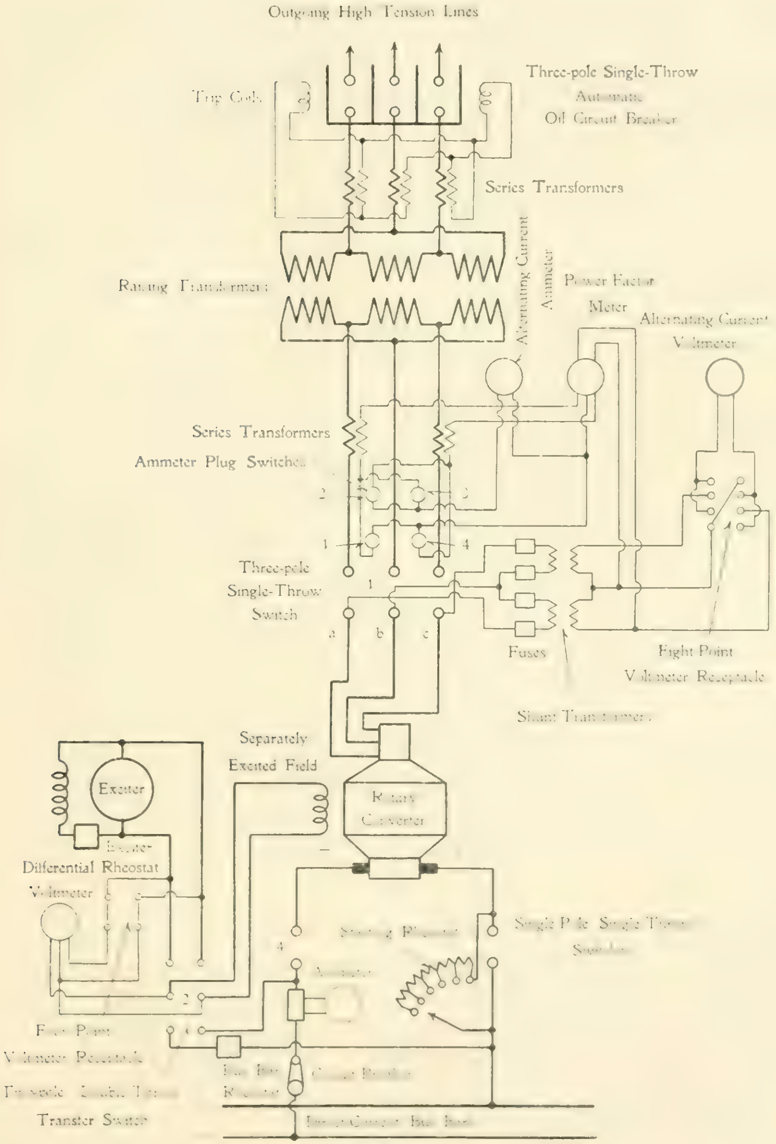
*Mr. Wagner's series consists of seven cases each accompanied by a full page diagram of connections.



CASE VII

Connections for starting one three-phase rotary converter, operating direct to alternating current, with direct connected exciter.

It is the usual practice to operate the oil circuit breaker trip coils with three series transformers at one end of the transmission lines. Otherwise the system would not be properly protected against a ground occurring in that line unprovided with a series transformer. This third series transformer is generally supplied on the outgoing lines, being connected in reversed delta with the other two as shown in the diagram.

A rotary converter operating from direct current to alternating current has no longer a constant speed. When a converter is driven by direct current, its speed follows the law of a direct-current motor and is governed by the strength of the field, and therefore by the reaction of the armature current upon the field. Armature reaction increases only slightly with a non-inductive load, but when the load is composed of motors, transformers or arc-lights and is thus inductive, the armature reaction rapidly increases, due to the lagging current. In such a case the field is weakened and changes of load may result in excessive and dangerous speed if there is an application of a heavy inductive load. This may, however, be overcome by separately exciting the converter from a generator, the speed of which varies directly with that of the converter, particularly if the field of this exciter generator is unsaturated at normal voltage. Then any variation in the speed of the converter will cause a much greater variation in the exciting voltage, and the field of the converter will be changed in strength equal and opposite to that change produced by the character of the load.

Thus the speed of the converter will be constant, being independent of the amount or nature of the load. This exciter generator is generally direct connected to the converter.

GENERAL DIRECTIONS

(1) If while operating, the direct-current circuit breaker comes out, see that the alternating-current circuit breaker is still in and read the current in all the lines on the alternating-current side. If the currents in the lines are unequal or large to a great extent it is good evidence of a ground in the machine; should the currents indicate nothing wrong, open the switch in the same line with the direct-current circuit breaker, then close the latter and afterwards the switch. If the circuit breaker continues to come out it is best to shut down, locate and remedy the trouble.

(2) If the alternating-current circuit breaker comes out, it is of course necessary to open up all connections and synchronize in the same manner as when starting.

(3) If two or more converters are operating in parallel, and one falls out of step, as soon as possible reduce the load to a minimum on the converter giving trouble by lowering its voltage with the rheostat, thus throwing the load on the other converter. Then open the direct-current circuit breaker and switches and synchronize as usual.

(4) A rotary converter may flash or buck over due to excessive sparking, which affords a path for the current to follow; rapid variation in the load, or, what amounts to the same thing, the opening of the alternating or direct-current circuit breakers may also cause a flash over, due to the sudden shifting of the field. These troubles frequently cause a reversal of polarity in the converter-fields, making them build up in the wrong direction as noted by the direct-current voltmeter. Should this reversal occur it will be necessary to flash the fields. This can be done by opening the field circuit at a convenient point, and with the rheostat all cut in, separately excite the field for a short time from some outside source. If no separate source of supply is at hand the polarity of the converter can be reversed by shifting the brushes one pole, or reversing both the shunt and series fields of the machine.

(5) When the alternating-current power goes off, shut down the converter at once, opening all connections except the alternating-current circuit breakers. By closing the synchronizing plugs the lamps will indicate when the power comes on again.

Editorial Note—Case VII. will conclude this series since the author has been able to cover the subject with seven diagrams instead of eight, as was originally intended.

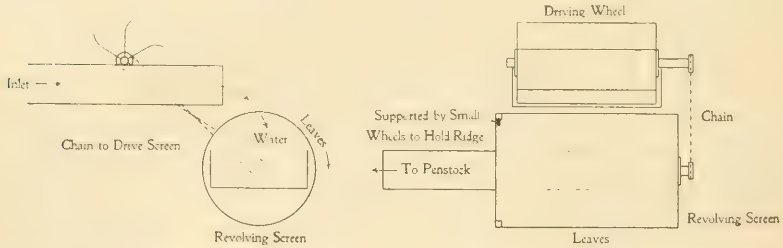
SOME TRANSMISSION TROUBLES IN THE FAR WEST

G. W. APPLER

Superintendent of Construction, Northern California Power Company

THE greater number of the troubles encountered in the west are due to climatic and physical conditions of the country rather than to the apparatus. Most of the purely electrical problems in connection with long distance transmission have been solved, but the application of machinery to rocky mountain wilds involves matters which cannot be settled in the laboratory or the testing room.

At the power house at Volta, Cal., the exciters consist of two 45 kw units driven by either water wheels or induction motors, the water pressure being about 140 pounds at the nozzles. During heavy rains leaves would wash into the ditches thence to the penstock, clog up the screens and stop the exciters. In order to



REVOLVING SCREEN TO PREVENT LEAVES AND OTHER OBSTRUCTING MATERIAL FROM PASSING INTO THE PENSTOCK

overcome this it was necessary to provide some device that would automatically remove the leaves before entering the penstock. The accompanying sketch illustrates the scheme. The water passes through the cylindrical screen while the leaves are rolled off on the outside. This ingenious device has been operating very satisfactorily ever since it was put in operation.

In the second plant at Kilarc instead of having a separate pipe line for the exciter supply, water is taken from the main pipe line, driving the exciter with the same water pressure as used on the big wheels, namely 515 pounds, with a $\frac{5}{8}$-inch tip, developing 45 kw. From all tests which have been made this has proven the more reliable way. There is less danger of cutting off the exciter water supply.

After the pipe line was filled for the first time, the nozzles of the big water wheels were closed and the exciter nozzles opened and left running for about a month, giving them a good test to ascertain if they would choke up, as the water was very muddy until the ditches and reservoir had settled.

There are also induction motors connected to each exciter for emergency, but it has proven bad policy to allow the motors to float on the bus bars, for in case of a short-circuit, the motors hold back or slow down with the generators, when the most power is required from the exciters. It is therefore left to the alert station man to close the induction motor switch in case the water should go off the exciter wheels.

The main line gave practically no trouble up to Feb. 14, 1904, excepting a few cases where insulators were shot off by hunters. On this date, however, a severe storm passed over the state, followed by unusually high water which gave considerable trouble.

The main line from Volta to Keswick, about forty miles, is double circuit on one pole line and spans the Sacramento River at Redding. On the east side of the river a heavy concrete foundation or pier was put in and the span pole fastened to it. The river rose very high and stayed up some three months. The concrete pier was undermined and the pole tilted up stream about 80 degrees. When this happened, the insulators broke, letting the wires of both circuits down on the cross arms. The line voltage is 26 000 and power was delivered over the line in this condition during a heavy rain for two hours until the smelter could prepare for a shutdown long enough to replace the insulators. Everything was gotten in readiness, the pole was reached by boat after several attempts, the power was shut off and new insulators were put on in a very short time.

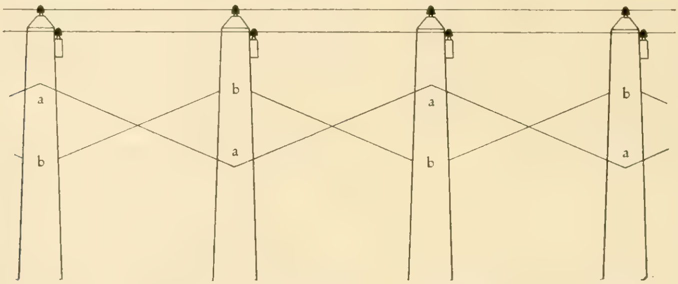
This is the first and only time that the power has been off the main line during its three years of service, and then only for about three hours.

During the same period the line running south to Willows about eighty miles and crossing the Sacramento River at Anderson, twelve miles south of Redding, was completely washed out and the only possible thing to do was to build about five miles north and there cross on a bridge, using two miles of an irrigation circuit constructed for 2 000 volts, which during the winter was not in use. It was a case of taking chances on anything, so the ordinary 2 000 volt single petticoat insulators already on the ir-

rigation line were used, which withstood the 26 000 volts for nearly two months of almost continuous rain.

Many creeks in summer are entirely dry, but rise twenty feet in twenty-four hours after a storm and are twelve hundred feet wide, changing their courses almost hourly.

On the twenty miles of line from Kilarc to De La Mar a special telephone line construction is used which has proven very successful, both in regard to induction and danger of crossing up with the power lines. The main power line is transposed every three miles while the telephone is transposed at every power transposition and once between and at the same time zig-



A TELEPHONE LINE THAT HAS GIVEN GREAT SATISFACTION ON THE POLES OF A TRANSMISSION LINE.

zagged up and down from pole to pole. Reference to the sketch will explain this construction. The wires do not cross each other horizontally but vertically. The wire *a* is on the one side, the wire *b* is on the other side of the poles, changing from one side to the other at transpositions.

Our next and most important change is to do all high tension switching outside of the buildings with pole switches operated by hand inside the stations by means of chains in a manner similar to the operation of railway signals.

A SHORT CIRCUIT DEVICE

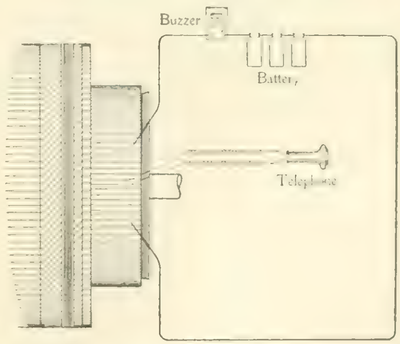
TO LOCATE SHORT CIRCUITS BETWEEN ARMATURE COILS WITHOUT DISCONNECTING THE WINDING

H. GILLIAM

IT is often necessary to test a closed winding without disconnecting the winding from the commutator.

A convenient device for this work consists of three dry battery cells, a buzzer for interrupting the current and a telephone receiver.

A short circuit can readily be located by passing the interrupted current from this apparatus through the winding, as indicated by the sketch, and then moving the leads from the receiver from bar to bar on the commutator. If there is a short circuit between the bars of the commutator or winding, there will be no audible vibration in the receiver. If, on the other hand, the winding and commutator are clear of short circuit at the point tested it will be indicated by a distinct vibration or buzzing.



In the case where an alternating circuit of 200 or 100 volts is at hand a more convenient method of finding a short circuit is to attach the leads of this circuit to almost any part of the commutator of the armature to be tested. Then the same method as before can be followed with the result that the vibration is much more distinct than in the former case, and the ceasing of these vibrations can be more easily marked. In the first experiment a current of a few amperes in series with a small resistance was used, but this may vary slightly provided that enough resistance is put in to prevent burning the winding.

The vibration is much more distinct in the case of the large armatures than in the smaller ones, probably due to the difference in the transformer effect of the various sizes of armatures.

The same experiment was tried with a magneto box instead of the shop circuit. In this case no sound whatever could be obtained either in the winding or the commutator.

FACTORY TESTING OF ELECTRICAL MACHINERY—XX

By R. E. WORKMAN

INDUCTION MOTORS—Continued

To Find the Power-Factor for any Current—In Fig. 86 *OA* is a vector representing the current in the motor. *BA* is the power component of this current in phase with the terminal e.m.f. *OD*. Then $\frac{BA}{OA}$ will be the power-factor and the angle Φ will be the angle of lag.

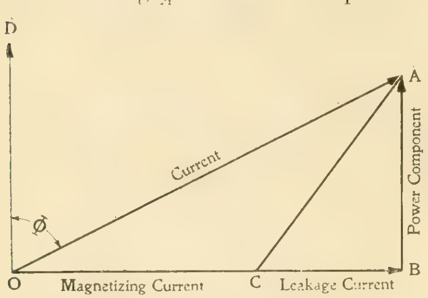


FIG. 86

The wattless component of the current *OB* is made up of two parts, of which *OC*, the magnetizing current, is constant, while *CB* is proportional to the current in the motor. The part *CB* is that required to overcome the counter e. m. f. due to leakage. The magnetizing current is very nearly the current taken by the motor running at no-load with full voltage across its terminals. This is taken directly from the running saturation curve and is, in this case, 9.82 amperes.

The leakage current is found from the locked saturation as follows:

At any convenient voltage as near as possible to the full voltage, reading of watts and amperes are taken from the curves. From the product of the volts, and the amperes the apparent input is found, in volt-amperes. If this and the real input are squared and the square root of their difference calculated, the result will be the wattless component of the volt-amperes input.

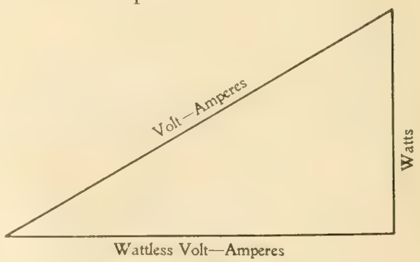


Fig. 87

This will be obvious from a consideration of the triangle shown in Fig. 87. At 200 volts, on the curves shown in Fig. 83, Vol. II, p. 453, the current is 86.2 amperes and the power component is 8 360 watts. The wattless volt-amperes will then be

$\sqrt{(200\times 86.2)^2-8\,360^2}=15\,090$

Similarly, the wattless volt-amperes from the running saturation curves are found to be:

$\sqrt{(200\times 9.82)^2-294^2}=1\,940$

The wattless volt-amperes due to a load of 86.2 amperes will be

$$15\,090-1\,940=13\,150$$

If this be divided by the square of the locked current, 86.2 amperes, a quantity K equal to 1.77 will be found, which is the inductive resistance or the inductive volts per ampere of the primary and secondary together and is constant for all voltages.

If this quantity be multiplied by the percentage power-factor (assumed), and the current for any given load, and divided by the terminal voltage of the motor, the resultant will be very nearly the percentage leakage current, *CB* in Fig. 86.

$$\frac{1.77 \times .84 \text{ (assumed)} \times 40 \text{ (amp. load)}}{200}=29.7 \text{ per cent.}$$

The percentage magnetizing current is $\frac{9.82}{40}=24.6$.

Referring to Fig. 86 if the line *OA* is 100 per cent. the line *OB* will be $29.7+24.6=54.3$ and the power-factor will be

$\sqrt{100^2-54.3^2}=84$ per cent.

In case this result does not check with the assumed power-factor, another assumption must be made and the calculation repeated.

Knowing the power-factor, the current input, and the terminal voltage, it is possible to find the apparent horsepower input and the real horsepower input, the latter being found by multiplying the former by the power-factor. In the particular case under consideration, at 40 amperes, the apparent input $=40\times 200=8\,000$ watts $=10.71$ hp.

The real input $=8\,000\times .84=6\,720$ watts $=9.00$ hp.

THE PRIMARY COPPER LOSS. The resistance of the primary winding—taken between terminals and is therefore the resistance of two legs of the star in series—of this motor which is star connected is 1.08 ohms at 50 degrees centigrade. The copper loss at 40 amperes is therefore $40^2\times 1.08 \div 2=864$ watts.*

THE IRON AND FRICTION AND WINDAGE LOSSES. This may be

* See "Applications of Alternating Current Diagrams," Part V, [illegible] *Electric Journal*, Vol. I, p. 271.

assumed to be equal to the real input at no-load, at full voltage, minus the primary copper loss, and is in this case:

$$294-(9.82^2 \times \frac{1.08}{2})=242 \text{ watts.}$$

The total primary loss is therefore, 864+242=1 106 watts.

THE INPUT TO THE SECONDARY—The secondary input is 6 720—1 106=5 614 watts.

In order to find the brake output from this last quantity it is only necessary to multiply it by the ratio of the motor speed under load, to the motor synchronous speed, equal in this case to $\frac{768}{900}=$ 0.853. See Fig. 85, Vol. II, p. 517.

Hence the brake output of the motor at 40 amperes is, 5 614x0.853=4 788 watts, or 6.42 hp.

The speed at this load is 768 r.p.m.

The torque is therefore, $\frac{6.42}{768 \times 0.0001902}=43.8$ foot-pounds.

THE SECONDARY COPPER LOSS—As there is practically no iron loss in the secondary, the secondary copper loss is simply the difference between the input to the secondary and the brake output, or 5 614—4 788=826 watts.

In testing a motor with a wound secondary the secondary current may be measured and the brake horsepower will then be found by simply subtracting all the losses from the real horsepower input.

The secondary copper loss will be found directly from the resistance of the secondary and the secondary current. In plotting the complete curves, a number of different currents are chosen and the above calculations made for each, the results being plotted as those shown in Fig. 84, Vol. II, p. 516. A very useful empirical relation between the percentage leakage current and the ratio of pull-out torque to the torque at a given current is the following:

$$\text{Per cent. leakage current} = \frac{\text{Torque at the given current}}{\text{Pull-out Torque}} \times 40.$$

TO BE CONTINUED

EDITORIAL COMMENT

Single-Phase Railways

The article by Mr. R. P. Jackson on "Single-Phase Alternating Current Car Control" which appears in this issue is of special interest as indicating the latest practice in single-phase traction and in pointing out the line on which future development may be expected.

One of the notable features is the abandonment of the induction regulator. The ideal simplicity and refinement of this method of control has been found to be an unnecessary and moreover expensive luxury. It is unnecessary when four or five steps in a voltage control with single-phase current will give a smoother acceleration than nine or ten steps with direct current. It is expensive because of the greater weight and cost of the regulator over either the drum type or the unit switch control. The step by step control is likewise more efficient than the regulator. Its losses are less and the regulation is more satisfactory on low power-factors.

It is interesting to note also that the design of satisfactory drum and unit switch controls for alternating currents greatly simplifies the problem of operating the single-phase equipments over existing direct-current lines. This will now be possible with very slight addition to the straight alternating-current control equipment. We may therefore confidently expect a rapid increase in the number of single-phase lines where the necessity for the double control system has heretofore prevented its adoption.

Altogether the prospects of the single-phase railway system are wonderfully bright. At least six lines are in daily commercial operation in this country. The troubles incident to the use of an entirely new type of apparatus are being rapidly eliminated and success is assured.

N. W. STORER.

Why Some Engineers Fail

An engineer of wide experience both in this country and abroad who now holds an executive position with a progressive company remarked that in selecting young engineers for specific work he found *a greater number were lacking in moral qualifications than in technical ability.*

He did not restrict the term moral to mean simply common honesty, but used it in a broader sense to include courage, judgment, backbone, moral strength and all those things which make up the complex called character.

When Mr. Kerr* gives the embryo engineer a new point of view he does not discuss equations and differentials, but he has a good deal to say about other things. A gentleman who was invited to give a word of council or suggestion to young men through the JOURNAL replied, "I have nothing to say. There is nothing left for me to say. Mr. Kerr has said it all. Every time I read his article I am more impressed with its keenness and completeness."

When Mr. Taylor† talks to young men of the future he assumes that engineers will know their engineering, but lays great stress upon the qualities which are essential to make it effective.

Now these four men, Mr. Kerr and Mr. Taylor, the man who finds more engineers with good slide rules than with good backbones and the man who has no new point of view to present, are all leading men in several large engineering and industrial companies. They have to do with men, they know from experience whereof they speak.

It is easier to train engineers than it is to develop men. College courses are apt to give 99 per cent. to technical subjects and one per cent. to culture studies. Were the divisions 85 per cent. and 15 per cent., one would be decreased by only a seventh while the other would be increased fifteen fold. When older men talk about the value to an engineering student of a debating society, of familiarity with parliamentary practice, of fluency in composition, of culture studies, of the training in effective cöoperation which may be secured through student organizations, of education as a means of forming right habits and developing the faculties as well of acquiring technical knowledge, the student in engineering does not seem to understand what they mean.

The development of this broader side of life must be after all a matter of individual choice and effort. Others may counsel, they may inspire. The result depends upon the man himself, upon what he chooses to bring within the range of his experi-

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*The Point of View, *The Electric Club Journal,* Vol. I., page 563.

†The Man of the Future, *The Electric Journal,* August, 1905.

ence and upon the success with which he assimilates that experience in his growth.

No one who has caught the spirit of the modern engineer will think that this applies to school days only. The principle of progress is to keep on. The ideal is not static but kinetic, as well for the individual as in society and science and engineering.

CHAS. F. SCOTT.

Insulation Testing

Dielectric tests on insulation are made for two purposes: (1) To determine the ultimate disruptive strength of the material or apparatus. (2) To determine whether the material or apparatus will stand a given test. Both classes of tests are made by means of the same testing devices, and the methods to be followed in making the tests are very similar. The paper on "Insulation Testing—Apparatus and Methods" begun in this issue, gives a resume of the principal methods and apparatus available for making such tests. This paper should be valuable to all who have to do with this class of work—whether the producer or the user of the apparatus. Special attention is directed to the paragraphs covering the determination of the size of testing apparatus necessary for any given purpose. There has been much misconception in the past by those not familiar with the subject as to the necessary capacity of testing apparatus for any given work. The determination of this point is a comparatively simple matter when the necessary constants are known.

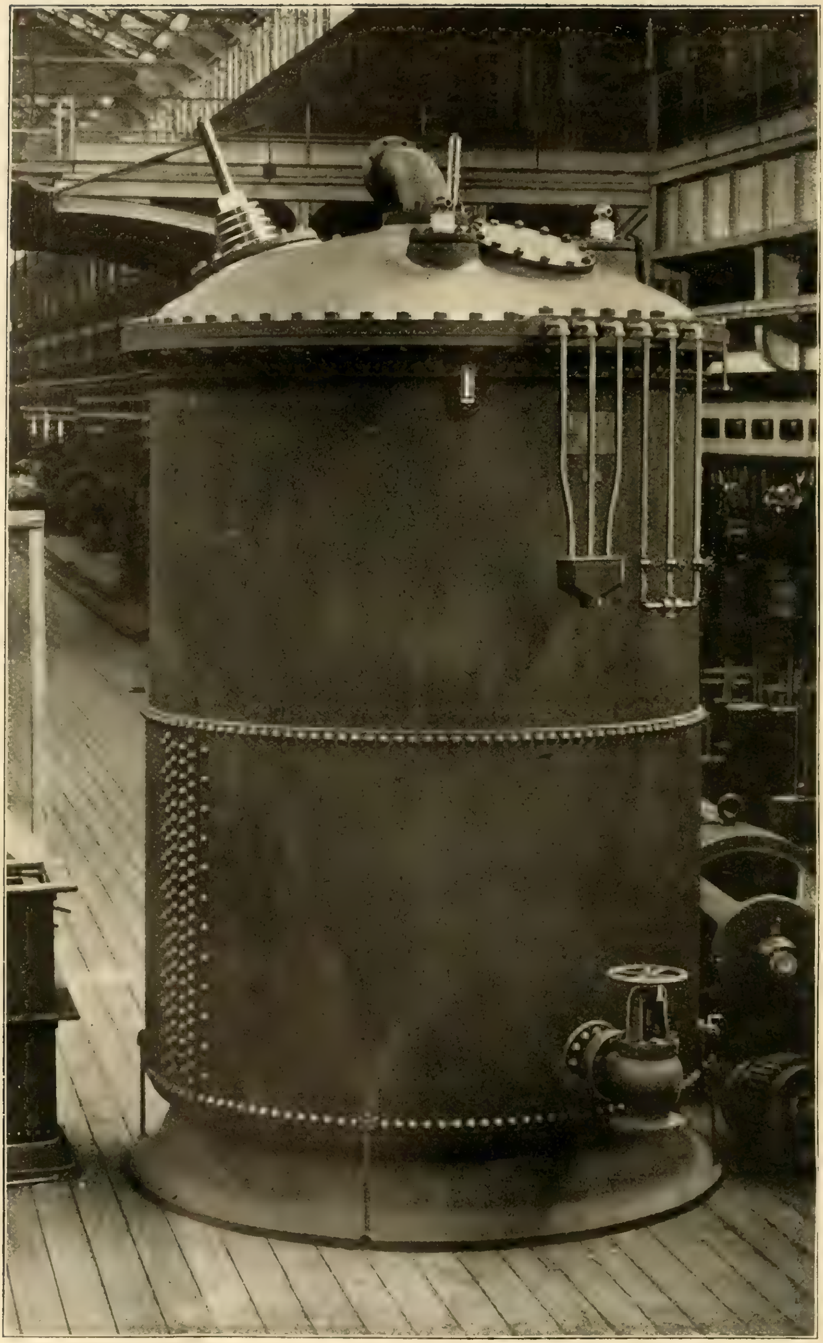
The paper as a whole covers the subject in a comprehensive manner, and is the first published outline of the fundamental principles underlying the selection and use of apparatus for making dielectric tests.

Armature Short Circuits

The determination of the precise location of a fault in insulation is sometimes very different by ordinary methods. Years ago an armature for a railway motor which may have had a short circuit between the turns in the first coil or between some of the first few coils put in place, had to be completed with connections made to the commutator and with bands in place in order that it could be put in its field and run on test before a bit of smoke would indicate that there was a fault. Even then it was difficult to locate the defect unless the burning of the in-

sulation were so great as to damage other coils. The armature had to be dismantled for repair. The taking off and putting on of the good coils did not improve their insulation, and altogether the procedure was slow, expensive and harmful. A special testing method was desired by which alternating current on a coil on a separate primary core was brought up to the surface of the armature so that the alternating magnetic flux passed through the armature core. A short circuit in the armature caused a short circuited secondary turn on the magnetic circuit which was indicated either by an instrument in the primary circuit or by the attraction of a bit of iron held near the armature surface which resulted when there was a secondary current in the armature. This test could be applied when a few coils were in place as well as when the armature was completed.

The ingenious method of testing for armature short circuits described by Mr. Gilliam requires no appliances other than such as are easily available. Such ingenious devices are of the greatest value in saving time and labor. In general principle this method is similar to the one above referred to. Instead of a separate primary circuit the armature winding is made the path of an alternating or intermittent current and any inequality in the insulation is detected by the telephone.



ONTARIO POWER TRANSFORMER

3 000 kw, 62 000 volts. Weight, 95 000 lbs. For description see page 600

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THE SINGLE-PHASE RAILWAY SYSTEM*

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IT is the purpose of this paper to present some of the salient features of the single-phase railway system, and the results of the work which has been accomplished in the development of apparatus to meet the increasing demands in electric traction.

The questions which a railway manager is apt to raise with regard to the single-phase railway concern its suitability for his particular conditions, its present practical status and its cost. The answers which apply in one case may be misleading in others, so that the discussion of the subject must be general rather than particular.

There are two other questions which have been asked so often that they deserve a passing comment: Will the motor start with good torque and accelerate rapidly? Will it commutate? Suffice it to say that the single-phase motor of the variety which I am considering does start and accelerate and commutate.

It is not the motor itself, but the single-phase system which the motor makes possible that is of prime importance. And the system is of commercial value only as it is able to operate electric railway service more effectively and economically than is practicable by other means.

SINGLE-PHASE AND DIRECT CURRENT SYSTEMS COMPARED

The single-phase system accomplishes the same results in car movement that may be obtained by direct current equipments, but in many cases with less first cost, less operating expense, increased flexibility and greater simplicity.

The radical difference between railway systems using direct

*Paper read before the American Street Railway Association, Philadelphia, September, 1905.

current motors and those using single-phase motors is not so much in the car or the power house as it is in the circuits connecting them. In the first place, the high voltage used on the trolley wire does away with expensive feeders and it also enables the current to be carried to a greater distance from the power house or from the sub-station. Second, the sub-station employed in the single-phase system requires simply a lowering transformer. The sub-station for supplying a direct current railway requires the rotary converter and a set of lowering transformers. Third, the number of sub-stations for a single-phase road is less than is required for direct current, and these do not require the attendance which is necessary for the operation of rotary converters. It is these characteristics that peculiarly adapt the single-phase system to interurban and long-distance railways.

CONSTITUENT PARTS OF SINGLE-PHASE SYSTEM

The motor is the feature which has received particular interest and comment, for it has been conceded that if a single-phase motor be available the other elements would follow as a matter of course. No one has questioned the adaptability of control apparatus, transformers and high tension line construction to the requirements of the single-phase railway system. This simply involves the application of well-known apparatus and methods to the particular requirements of railway operation. But a perfected motor does not mark the completion of development work. Control apparatus for handling alternating current must be devised and constructed. It must be suitable for hand control for small cars and it must be adapted for the multiple unit operation of heavier equipments. Still other forms must be suitable for operation interchangeably on either direct or alternating current. Transformers, line switches and other auxiliaries must all be combined into a workable equipment. Forms of trolley and overhead construction must be developed suitable for the new conditions of current and voltage. The announcement of a commercial single-phase motor, made in the paper of Mr. Lamme before the American Institute of Electrical Engineers three years ago this month, was necessarily the beginning rather than the end of the development of the system as a whole in all its details.

ADVANTAGES PROVED BY SERVICE

In how far have the advantages claimed for the single-phase system been realized? Among the important features are the following:

A high voltage trolley construction has been developed and has proved to be simple, strong and thoroughly practicable. Thirty-three hundred volts has been used and has proved to be safe and reliable.

A sliding contact device which does not require reversing when the direction of the car is changed is found more satisfactory, especially for high speed operation, than the trolley wheel. Its wearing surface lasts longer than trolley wheels operating lighter cars on direct current.

Transformer sub-stations supply current satisfactorily without feeders and without station attendants.

The car equipments show simplicity and effectiveness in the control apparatus. Less than half the controller notches required for direct current give equally smooth and as rapid acceleration with alternating current. Platform controllers are simpler, as no magnetic blow-out is required. The multiple unit control system is readily adapted for the operation of single-phase motors and is in some points simpler than the control of direct current motors.

The operation interchangeably by alternating current and by direct current is a feature of an important road which operates large equipments on direct current in the city and on alternating current across country.

Motors of four or five sizes have been built and show excellent commutating features. The communtators take a good polish. The motor windings are such that there is a practically balanced magnetic pull, even if the armature be slightly out of center. Although the armature speed is higher than in corresponding direct current motors, the advance criticism has proved ill founded, as there have been no bearing troubles. The oil lubrication has proved highly satisfactory.

The foregoing features, which are the important elements upon which the claims of the single-phase system are based, have been shown by actual operation to be entirely feasible and practicable and such as to inspire confidence.

Difficulties have been met which have been annoying and vexatious. The difficulties, however, have usually been due to some error in the general engineering features or to some specific point of weakness in the insulation or construction of some part of the apparatus. In other words, the troubles have not been fundamental and inherent in the single-phase system, but have

been incidental and capable of ready remedy. Some particular difficulties will be taken up further on in this paper.

LEADING FEATURES OF SINGLE-PHASE SYSTEM.

As a guide to determine the conditions under which the adoption of the single-phase system is advantageous it will be useful to review briefly some of its features which are particularly concerned in its installation and operation.

The Motor—A motor which is protected from the trolley voltage and lightning disturbances by an intervening transformer winding, which has only 200 to 250 volts across its terminals, which may have its brushes grounded or short circuited without "flashing" or "bucking," and which may have full voltage thrown on its terminals without disaster to itself, is essentially a safe motor. The armature has a bar winding on sizes of 30 horse power and upward. The increased current required at low voltage necessitates brush capacity equivalent to that on a direct current motor of twice the output.

The Control—One usually thinks of the direct current street railway motor as a variable speed motor. Yet it is, in a sense, fundamentally a one-speed motor, for with definite trolley voltage, weight of car and grade, the motor soon attains a definite speed, at which it continues to run until there is a change either in the voltage applied or in the load. If two motors be operated in series there is a second definite speed, which is about half of the speed when they are in parallel. Other speeds are obtained by lowering the voltage on the motor by means of resistance, but this is inefficient and is admissible only in starting.

Certain results follow. The speed of the car depends upon the trolley voltage. If the voltage be low, the speed is low. The efficient speeds are fixed by the trolley pressure and not by the motorman. The relation between speed on level and the speed on grade is fixed by the inherent characteristics of the motor. A given motor with definite gear ratio has its one definite speed depending upon train resistance and electromotive-force. There is no range of adjustment like the throttling of an engine without the introduction of the wasteful rheostat. In a series motor the current determines the torque and the electromotive-force determines the speed. Hence, for speed control there must be voltage control. In the direct current system efficient voltage control is not attainable, but with alternating current it is easily secured. The simplest method of variable voltage is by means of

taps from the transformer winding. The low voltage required for starting is obtained from a low tap and the successively higher voltages for increasing speeds are secured from successively higher taps from the winding. As there is no rheostat, the motor may run efficiently from any tap, thereby giving the motorman a control over his car movement which is not possible with direct current. If there be a tap giving a voltage higher than that required for normal running, it is available for giving a higher speed for making up lost time, or for supplying normal voltage to the motor when the line pressure is low. The car can run at any time at the pressure needed.

The number of points required on the controller for smooth acceleration is much less with alternating than with direct current. The whole control system, in fact, is simply half a dozen taps from the transformer to the controller, by means of which any one of them may be connected to the motor. An intervening preventive coil enables the controller to pass from one point to the next without opening the circuit or short circuiting the two taps. The controller may consist of a drum of ordinary form on the car platform or of unit switches placed under the car and operated by a master controller. The latter type is used in heavy equipments and also when several cars are to be operated in the multiple unit system. An effective form of switch with magnetic blow-out has been developed for heavy currents. The switches are assembled in a compact group, thoroughly protected and easily accessible.

Trolley Voltage—Twenty years ago the electric railways of the United States, as measured either in miles, in cars or in kilowatts, comprised less than 1 per cent. of what they do to-day. In this enormously rapid growth two features of the electric railway have remained unchanged, although other elements have been greatly modified. These two features are: First, the series motor; second, the use of direct current at approximately 500 volts. During this time the generating plant has changed from small belt-driven to large direct connected units and then from direct current to alternating current. High tension transmission circuits with rotary converter sub-stations have been common. Motors have increased in size and have been improved in design and in reliability and the multiple unit system of control has been introduced for larger equipments. The trolley voltage, however,

has been limited to approximately 500 volts on account of the limitations of the direct current motor and the inability to transform direct current on the car from a high voltage to a low voltage. The general trend of electrical engineering has been toward alternating current at high voltage. Many can remember the time when the use of 1 000 or 2 000 volts was decried as impracticable or unsafe and when 5 000 or 10 000 volts was the limit to laboratory experiments. Progress has been made in design, in construction and in materials until voltages, which not long since were impracticable, are now operated with greater reliability and safety than were the lower pressures a few years ago. Safety is very largely a question of mechanical excellence. In railway motors and control apparatus, in the mechanical equipment of heavy and high speed cars, in overhead construction and in power house equipment, reliability is primarily dependent upon mechanical excellence.

While any considerable increase in voltage may not be safe on existing trolley lines, it is practicable by an increase in mechanical strength to offset the higher pressure and produce a high voltage trolley system of greater reliability and safety than the present construction for low voltage affords. Such a construction has been developed into a commercial form in the catenary suspension of the trolley wire. An auxiliary steel cable with a moderate sag at the center of spans supports at frequent intervals the trolley wire which is thereby maintained at a uniform height. It is adapted for high speed running and it possesses a greatly increased strength. The excess cost of the catenary construction over the cost of poles and overhead construction of the ordinary type is moderate, and, in a large measure, is justified by the gain in mechanical reliability quite aside from the question of voltage.

The Sub-Station—To one familiar with an ordinary rotary converter sub-station interest will center chiefly in the negative characteristics of the single-phase sub-station. There is no rotary converter—a most essential link in the old system, one which behaves remarkably well when all is favorable but is inclined to be fussy and obstreperous when the conditions are not to its liking. There is no synchronizing, no sparking, no flashing, no dropping out of step. The transformers are not arranged in banks of two or three little ones, with polyphase switches and auxiliaries in primary and secondary, and the direct current switchboard has disappeared entirely.

So much for what it is not. In its simplest form the substation is a single transformer with its primary and secondary connections. Additional transformers, switches, lightning protection and instruments are added as circumstances require.

Short circuits have lost much of their terror. The alternating current on short circuit is limited by the self-induction of the circuit, and a transformer is not disturbed by a "short" as is the commutator and the speed of a rotary converter

The difference in the effect of a short circuit on direct current and on alternating current is well illustrated in the underground circuits in New York City. In an 11 000 volt cable system a fault in the cable causing a short circuit is usually confined within the cable and merely burns out a few inches of the conductor before the circuit breaker opens. On a low tension system, however, the currents are very large and considerable lengths of the conductor may be melted before the current is interrupted. In an alternating current system the normal current in a circuit delivering a given amount of power is less in proportion as the voltage is increased, and, as the increase of current above normal is not as great on account of the self-induction of the circuits and apparatus, accidents are less liable to be destructive.

OPERATION ON DIRECT CURRENT

If the single-phase road is to be an extension of an existing road it may be desirable to run the single-phase cars over the tracks which have a direct current trolley wire. While single-phase cars can be arranged to operate from a direct current trolley wire, it handicaps in some measure the single-phase equipment. The addition of resistance to the car equipment and the extra switches and the like for enabling the change to be made in the current supply are obviously objectionable. It is best, therefore, to keep single-phase equipments free from operation on direct current if it be practicable to do so. When it is found necessary for them to operate from an existing direct current trolley wire, the motors are connected two in series for 500 volts, and if there be four motors the two pairs may be connected first in series and then in parallel as in ordinary series parallel control. The transformer is cut out, and the control apparatus and motors operate in substantially the same way as those on an ordinary car.

SOURCE OF POWER

The standard frequency for the single-phase motor is 25 cycles,

(3 000 alternations). Generators may be wound for single-phase, or current may be taken from one phase of a two-phase or a three-phase generator. Current from the several phases of a polyphase generator may be used for operating different divisions of the railway.

If power is to be taken from a power house which generates a higher frequency it cannot be applied directly but must be changed to 25 cycles. This may be effected by a motor-generator set. A polyphase motor taking power equally from each phase of the high frequency circuit may drive an alternator, either single-phase or polyphase for furnishing current to the single-phase railway. The converting outfit may be located in the main power house or in a sub-station as may be found most convenient.

THE FIELD FOR SINGLE-PHASE RAILWAYS

The development of a new and more efficient method for accomplishing a given result often leads on and opens new fields which had not been commercially practicable before. Such is the case with the single-phase railway. The direct current interurban railway has its limitations. If a region be sparsely settled the available traffic will not show a profit on the cost of circuits and rotary converter sub-stations. There is a material reduction in the investment and operating expense incident to the single-phase railway that will enable it to be built and operated with a profit in cases where the traffic would not support a rotary converter system.

On the other hand, in heavy service the direct current has not made much headway, being handicapped by the heavy cost of sub-stations and of conductors. Heavy and relatively infrequent trains are the hardest loads for sub-stations. For example, if sub-stations be eight miles apart each will supply eight miles of track. A train running forty miles per hour will receive current from a given sub-station for 12 minutes. In order that a sub-station may be continuously supplying current to trains in one direction they must have a headway of 12 minutes. If they be an hour apart the current from each sub-station is used but one-fifth of the time. Trains in two directions will double the sub-station output, but as the peak load is considerable when two trains pass near a sub-station the load factor is extremely low. Therefore as the aggregate capacity of the sub-stations must be large in proportion to the actual power taken by the cars, it follows that the sub-stations will

involve a relatively large expense if they are equipped with expensive rotary converters and require constant attendance, whereas the cost will be relatively small if they require simply lowering transformers having an efficiency very much higher than the rotary converter sub-station and not requiring attendance. The reduction in the sub-station is therefore of especial value when the service is infrequent. Moreover the single-phase equipment by reducing the size of conductors frequently enables the sub-stations to be more widely separated. This possibility in the reduction in the number of sub-stations and in the aggregate capacity of sub-station equipment, as well as the elimination of rotary converters with their energy losses and their attendants makes practicable the operation of long distance roads which could be operated by direct current only at an excessive cost.

The single-phase system therefore decreases the cost of installation and operation for the kind of interurban service which has been successfully developed by the direct current, and it extends the field of commercial operation to include, on the one hand, rural roads with relatively light traffic, and on the other, a heavy, infrequent, multiple unit or locomotive service for passengers or for freight approximating steam railway conditions.

SINGLE-PHASE RAILWAYS IN OPERATION

The single-phase railway which shows the most extensive operation as measured in car miles is the Indianapolis and Cincinnati Traction Company. Operation was begun over a short length of track, January 1st and on April 1st 37 miles were covered. Since July 1st a regular schedule has been maintained over 41 miles, 37 miles of which is under alternating current trolley and the remaining 4 miles is under direct current trolley in the City of Indianapolis. The Company has 10 cars each equipped with four 75 hp motors. A maximum speed of 60 to 65 miles per hour is secured and the cars are not only the heaviest but they operate upon the fastest schedule of any of the numerous suburban roads radiating from Indianapolis. Some defects have developed in the equipment, which, however, have been incidental in character, and not in those new features where trouble might reasonably have been anticipated. It was found that the natural ventilation under the car was insufficient for the transformer and a ventilating motor was added. A weak point developed in the armature insulation when the cars, which had been running for some time by alternating current.

were first run regularly over the direct current lines into Indianapolis. One feature of the new condition was the opening of the circuit with four motors in series, the motors having laminated fields which give greater field discharge than solid poles. The remedy was obviously the strengthening of the insulation. This brings out the interesting fact that operation on alternating current at 3 300 volts with an intervening transformer is less severe upon the motor than operation on direct current at 500 volts. Experience showed wherein the control apparatus, suitable for both alternating and direct current, could be simplified and the apparatus reduced in quantity. The result is a control system which is relatively simple and compact, although suitable for operation interchangeably between alternating current and direct current.

The best verdict upon the working of the single-phase system on this road at Indianapolis has been given by the operating company. It is found in the contracts which have been placed for extending the present line a distance of 16 miles; also in extending the single-phase operation to the Shelbyville line, both to the 29 miles which have been operated by direct current and for a 20-mile extension. The length of track is therefore to be increased from about 40 to 100 miles; the number of cars will be double the present number and all equipments will be similar. It is significant that a company which has been operating two substantially similar suburban lines, one by single-phase current and the other by direct current, should see fit to throw out the direct current and substitute single-phase alternating current. It may be noted that this course was taken, although the reverse was easily possibly, as provision was made in the original contract for the single-phase apparatus by which it would be exchanged for direct current equipments if its operation proved unsatisfactory.

Other single-phase roads which are operating Westinghouse equipments show a variety of conditions, some having exceptionally sharp curves and steep grades. On the road between Derry and Latrobe, in Pennsylvania, 30-ton cars are started on a 10 per cent. grade. The cars have platform controllers and are equipped with four 50 hp motors. In some cases the initial operation has been handicapped on account of incompleteness, or through the use of temporary apparatus either in the power house or on the car. In its fundamental elements, however, the operation is proving perfectly satisfactory.

SOME NEW ROADS

The extension to long distances will soon be shown in the carrying out of the contract which has been closed by the Spokane & Inland Railway Company for 150 miles of railway running south from Spokane, Washington. The equipment will consist of 15 motor passenger cars each with four 100 hp motors, 6 motor freight cars, each with four 150 hp motors and six 40-ton freight locomotives which may be in pairs for heavy trains. The engineer of this road has been intimately connected with the installation and operation of the single-phase road at Indianapolis.

The most notable recent event in electric traction is the purchase of Westinghouse single-phase locomotives by the New York, New Haven & Hartford Railway Company. The passenger trains on this road which enter Grand Central Station in New York run over the tracks of the New York Central Railroad for about 12 miles. As steam locomotives cannot enter the new terminal station and as the New York Central is equipping its track for direct current it is imperative that the New Haven trains be handled over 12 miles by direct current power. Instead of changing from electric to steam locomotives for all local and through trains at the end of 12 miles it was decided to extend the electrification and to do it, not by extending the direct current, but by changing to alternating current. The single-phase locomotives will be designed so that they may operate interchangeably from direct current or from single-phase alternating current.

The adoption of the single-phase system by one of the leading railroads of the country for its heavy and important passenger service is all the more noticeable; first, because its officials are already familiar with electric traction matters through the operation of many important city and interurban railways in New England, and second, because the obvious thing to have done would have been to follow the example of the New York Central by adopting direct current locomotives. Probably this is the turning point, and the coming electrification of heavy railways will follow the conspicuous example set by the New York, New Haven & Hartford Railroad Company in adopting the single-phase system.

EXPERIENCE ON THE ROAD

AN INCIDENT WITH WATER COÖLED TRANSFORMERS

G. B. ROSENBLATT

Preconceived opinions in trouble work are a great hindrance in discovering true causes of difficulty. A case of rather unusual interest came to the writer's notice some while since.

Three fair sized water-cooled units connected in delta on a three-phase, 14 000 volt system and supplying a lighting and small motor load, were running hot. Their temperature had been steadily rising ever since their installation until at the end of a year they showed a temperature rise of about 55 degrees centigrade in the oil, even with an abundant supply of cold water flowing through the cooling coils. The maximum load possible could not tax the transformers more than 60 per cent. of their rated capacity and there was no reason to believe that there were any cross currents between the transformers. Evidently the trouble lay inside the transformers.

Much has been said and written of late concerning deposits in transformer oil, and in some cases these deposits have caused considerable annoyance to transformer operators. Inasmuch as the transformers in question showed measured losses no larger than they were designed for, the conclusion was immediately reached that the cooling coils were not working properly. This conclusion was corroborated by the fact that the temperature of the water leaving the cooling coils was but little higher than that of the entering water. It was a fair presumption that the only thing which could affect the action of the cooling coils was a coating that would impair their conductivity. A deposit from the oil? Yes, of course. An inspection of the cooling coils showed them to be covered with a thin vaseline-like layer of about $\frac{1}{8}$ inch in thickness—the sort of a deposit that may occur in any oil insulated transformer without materially affecting its operation or temperature. However, it was decided that this was evidence that there was a deposit from the oil, and that while the coating on the cooling coils could not account entirely for the high temperature of the transformers, it undoubtedly helped and surely indicated a deposit in the ventilating ducts between the windings.

Accordingly, the feasibility of cleaning out the transformers

was discussed and an engineer was sent from the works to make an inspection and to superintend the cleaning operation. So imbued with the oil-deposit idea was everyone connected with the plant that the engineer from the works never doubted the cause of the trouble as stated and that all there remained for him to do was to remove the cause. However, on removing some of the oil from one of the transformer tanks, he noticed the lightness of the deposit on the coils and began at once to have his doubts. Nevertheless he proceeded to have the oil removed from the tanks, if for no other reason than "to see what he could see." Meanwhile he took a walk about the plant and had a look at the general layout.

The transformers were installed in a separate house, containing in addition to two banks of transformers, the lightning arresters and arc light regulators. The cooling water was obtained from an artesian well under the engine room and was pumped from the well through about one hundred feet of iron pipe to the transformers. The iron pipe joined the brass tubing of the cooling coils about two feet from where the cooling coils entered the transformers and the waste water from each transformer emptied into a concrete tail race in the floor of the transformer house. The cooling water was quite cold and had a queer but not unpleasant taste. Where it left the waste pipe from the transformers the concrete of the tail race showed a reddish discoloration. A steel nut and an iron washer which had been in the race for some time were quite clearly outlined in red on the concrete. Probably there was iron in the water. Still it might not be iron. At any rate it was worth while looking into, particularly as there was nothing else to investigate until all the oil was removed from the transformers. So a section of the brass tubing at the joint between the cooling coils and the iron pipe was removed and the inside examined. Its entire inner wall was covered with a coating of a reddish brown material, solid near the brass and softer and slimier towards the center. The coating was about $\frac{1}{4}$ inch thick, which in the $\frac{3}{4}$ inch tubing of which the cooling coils were formed, left about $\frac{1}{4}$ inch clear for the water—just enough to pass a lead pencil. That was why the transformers ran hot.

Now that it was evident that it was not the fault of the oil, the problem presented itself of how to clean the inside of the cooling coils. The deposit was clearly not soluble in water or it would not have remained. The highest pressure that was available at the

powerhouse failed to remove any particle of it. Various solvents were tried—salt, ammonia, vinegar—but nothing weaker than 50 per cent. hydrochloric acid seemed to attack the deposit. However, the hydrochloric acid attacked the brass. It was evident that if the tubes were to be cleaned without removing them from the transformers (which on account of the arrangement of the high tension wiring would have been a most arduous undertaking), muriatic acid would have to be used and the job done with the utmost dispatch to prevent the brass being injured. Several gallons of the acid were obtained, mixed with water and poured into the tubes, the coils being filled from the bottom up to prevent water traps. From the sound of the disturbances, violent ebullitions must have taken place. When, after five minutes, the tubes were flushed by turning on the cooling water, the deposit came out in chunks. Such sections of the tubing that could be inspected seemed to have been thoroughly cleansed.

The transformers were refilled with oil, and upon being tested under full load showed a perfectly normal temperature, the oil not rising over 35 degrees centigrade.

The explanation, given by the chemist who was consulted, was that the artesian well water was acidulated and attacked the iron in the pipe from the well to the transformers, forming a salt of iron which was thrown down in the cooling coils by the heat of the oil. Had the cooling coils been of iron there would have been no such action, but they would have been slowly eaten away by the water.

One interesting feature of this case was the method of obtaining a full load on the transformers for the temperature run made after the cooling coils had been cleaned. As stated above, the maximum load available was about two-thirds of the rated capacity of the transformers. It was therefore necessary to find some means of energy consumption outside of the load. There were in the station two banks of transformers of like capacity, one bank which was running hot and another bank with which no trouble had been experienced. The troublesome bank was fed from a water-power plant some eight miles distant, the other from another water-power plant eighteen miles away. To obtain full-load, the low tension sides of the two banks of transformers were thrown together and the water wheels at the plant supplying the bank which was operating satisfactorily slowed down until they drew power enough through the transformers to constitute a full-load.

PROTECTIVE APPARATUS

CHOKE COILS

N. J. NEALL

LIGHTNING ARRESTERS have been chiefly dealt with in preceeding articles on "Protective Apparatus," but it should not be forgotten that they alone are insufficient to give complete protection to a plant.*

The disturbances which a lightning arrester is designed to take care of are assumed to be of a definite wave form and the nodes and loops especially on a surging line may so form themselves as to bring the arrester at a neutral point and therefore defeat its purpose. Use has therefore been made of a device variously called a reactive coil, choke coil, choker or kicking coil. It consists essentially of a number of turns of wire more or less insulated from one another, wound without a metal core and placed in the line wire in series between the lightning arrester and the apparatus it is to protect. The form may be either spiral or helical, though the majority of coils are made of the spiral form. Figs. 1 and 2.

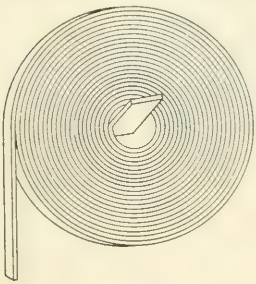

FIG. 1—CHOKE COIL, FLAT SPIRAL FORM

In its earliest use a number of flat spiral coils were placed in series in the line with taps to discharge gaps forming a pyramidal arrangement which is thought to afford a very complete discharge to ground, Fig. 3. This type of coil consists of a few turns of Underwriters' wire and no special insulation is placed between its layers.

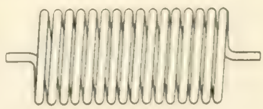

FIG. 2
CHOKE COIL, HELICAL FORM

A later form of practically the same coil, Fig. 4, was brought out by C. C. Chesney who wound his coil in two parts with these parts so placed as to cause a neutralization of their fields due to the passage of normal current but which curiously enough would afford protection at a time of static disturbance.

Other forms of choke coils are shown, one being of a well

*_The Electric Journal,_ Vol. II., p. 227.

known type for the protection of railway motors, Fig. 5, and the other, Fig. 6, similar in form, but mounted on a base for station use

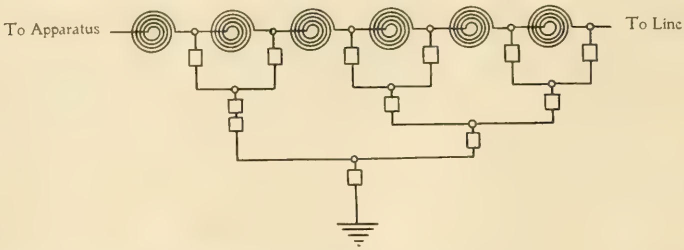

FIG. 3—CHOKE COILS USED IN PYRAMIDAL ARRANGEMENT OF LIGHTNING ARRESTERS FOR HIGH VOLTAGE CIRCUITS

forming a part of the well known tank lightning arresters.

During a recent measurement of skin effect on wires of different size and cross section, Fig. 7, it was found among other things that 50 feet of No. 8 or No. 9 bare copper wire placed in the equivalent spark gap set* in such a way as to be uninfluenced by its own field and by adjacent objects, had a surprisingly large equivalent spark gap, although its ohmic resistance is almost negligible. A further investigation of choke coils by the same set revealed the fact that approximately 80 per cent. of the choking effect is due to the skin effect of the wire and about 20 per cent. to inductance of small wire. For large wire this result would of course be somewhat modified. Further investigation also showed that for the same length of wire that the flat spiral form has more inductance than the helical form with turns close together. Obviously the greatest choking effect is obtained from coils using relatively small wire in a maximum of length and of the flat spiral form. A new

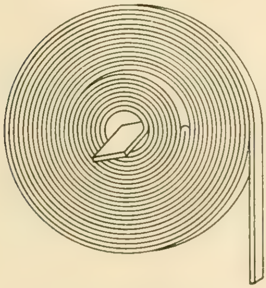

FIG. 4 — COMPENSATED CHOKE COIL DEVISED BY C. C. CHESNEY

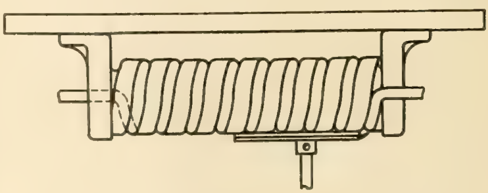

FIG. 5—GENERAL DETAIL OF A CHOKE COIL USED ON RAILWAY CARS. THE COIL IS WOUND IN A SPIRAL GROOVE CUT ON A CORE OF INSULATING MATERIAL

*See *The Electric Journal*, Vol. II., p. 224.

form of helical choke coil just brought out by the General Electric Company is shown diagramatically in Fig. 8, the idea being that the compression of the central part increases its inductance. Owing

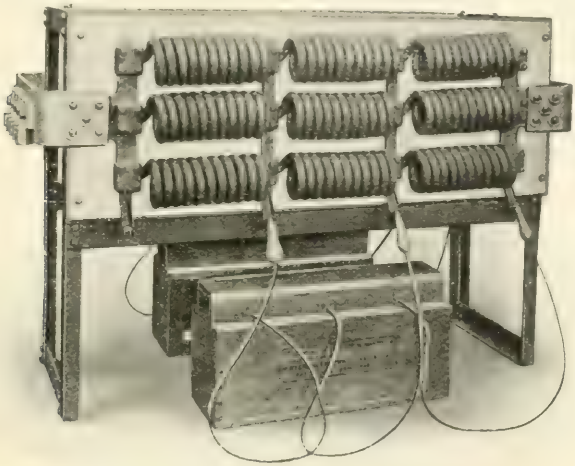

FIG. 6—CHOKE COIL USED IN RAILWAY SERVICE. DESIGNED FOR STATION USE

to the large wire of which this form is usually made it is doubtful if the increase adds greatly to its protective power.

The same test shows that if the copper wire is placed so as to make a return circuit with wires a short distance apart throughout (shown dotted in figure) the equivalent spark gap is materially re-

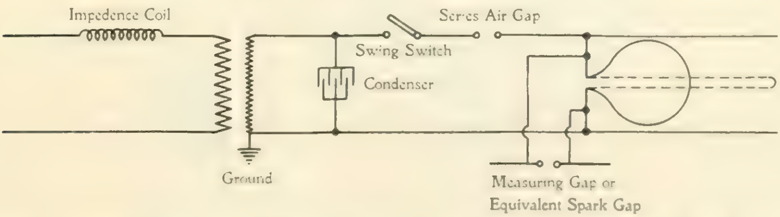

FIG. 7—DIAGRAM OF CONNECTIONS SHOWING THE MEASUREMENT OF THE SKIN EFFECT OF ORDINARY TRANSMISSION WIRE

duced but not entirely eliminated. This fact explains the action of the Chesney coil. The residual equivalent spark gap, as we term the above, represents the protection it could afford. It is needless to say that the same amount of wire in a plain spiral form would

probably still have a negligible line drop and yet give more effective protection.

Standard choke coil design usually has a voltage drop due to normal current of less than .5 per cent., which is certainly not to be considered an excessive amount.

The most important requirements of a choke coil are a large surface for ventilation in order to keep the insulation of the coil unimpaired by heating so that it will resist breakdown at normal strain, and again to have the insulation so placed as absolutely to prevent side flashing at the time of disturbance. The latest types of coils have this property in a remarkable degree. Fig. 9 shows a cross section of a Westinghouse type 7 coil from which we clearly see how difficult it would be for a side flash to occur and therefore how perfectly the coil performs its throttling effect. After

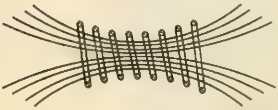

FIG. 8

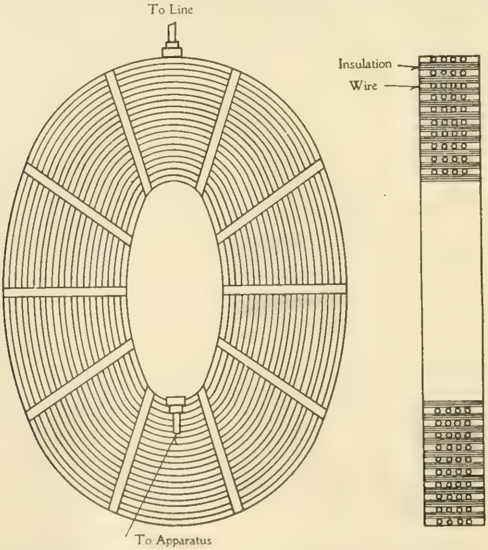

FIG. 9—CROSS SECTION OF A WESTINGHOUSE CHOKE COIL, SHOWING METHOD OF INSULATION

this, air insulation may be employed by separating each turn by an air space, a practice commonly followed in the helical form, but suitable for only certain coils and then of more or less doubtful value.

For example, if a coil is made up in a helical form with insulated cable in contact, a test on the equivalent spark gap set would

cause a discharge to pass right over and not through the coil. Moreover the general form and dimensions of this coil render it low in protective power; for example, where such a coil for 25 000 volts may have only $\frac{1}{2}$ inch equivalent spark gap a well insulated spiral coil may run 9 to 10 inches.

During a long study of static phenomena made by Mr. Percy

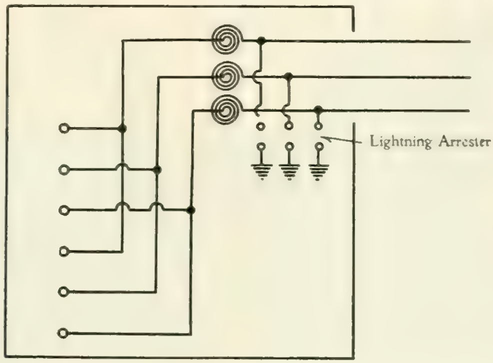

FIG. 10

H. Thomas, it was found that switching, short-circuits, ground, etc., produced a strain on the terminals of transformers, and other apparatus, which made it of the utmost importance to provide special protection for these parts. A new idea therefore arose in the application of choke coil protection, namely that it was better to

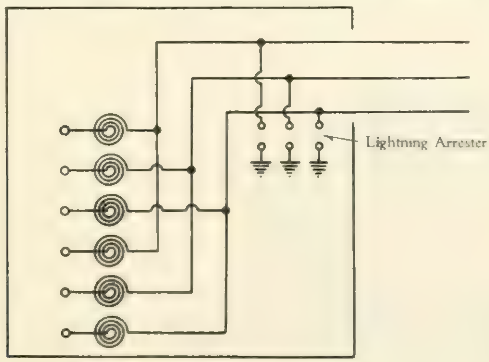

FIG. 10A

have choke coil protection at the leads of all apparatus feeding the high tension line than to couple these directly with the lightning arrester as heretofore. Let me illustrate. Fig. 10 shows the earlier

application of the choke coil, the only requirement being to have coils of sufficient carrying capacity for the plant. Later designs in Fig. 10a, call for coils at the terminals of each group of

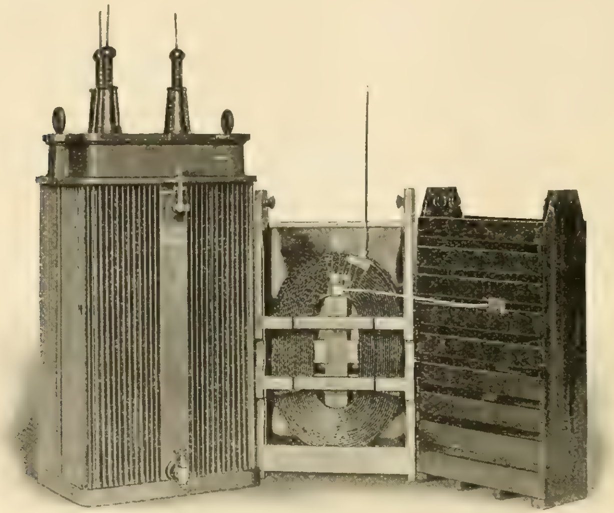

FIG. 11—SPECIAL CHOKE COIL PROTECTION. SINGLE POLE STATIC INTERRUPTER; VIEW OF INTERRUPTER ASSEMBLED; ALSO OF THE COIL AND THE CONDENSER BEFORE ASSEMBLING

apparatus, thereby giving more flexibility of operation and less original expense of layout.

A special form of choke coil protection was later devised and

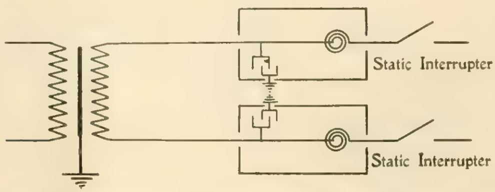

FIG. 12—DIAGRAM SHOWING APPLICATION OF STATIC INTERRUPTER TO A SINGLE-PHASE CIRCUIT

called the static interrupter, Figs. 11 and 12. This device consists simply of a choke coil and a condenser immersed in oil, the condenser being connected from line to ground at a point between the coil and the transformer it protects, Fig. 12. The transformer iron

is grounded. This arrangement secures the effect of a much larger coil with a consequent reduction of strain on the transformer terminal, as the coil acting in its ordinary capacity is greatly assisted by the condenser. The whole affords a greater protection to apparatus than that given by any other form of protection.

FIG. 13—CHOKE COIL FOR EXTRA HIGH TENSION SERVICE OF THE OIL INSULATED SELF-COOLING TYPE

In addition to the above a special oil insulated self-cooling coil is manufactured for extra high tension work (shown in Figs. 13 and 14) having all the advantage of the static interrupter insulation although not so effective in its protection.

It should be borne in mind that measurements made in service show that potentials higher than double voltage seldom occur and therefore in consideration of the quality of insulation now used in high tension apparatus special terminal protection is no longer absolutely required. It should be remembered, however, that certain forms of choke coil protection such as the static interrupter represent the highest form of protection; and it might be advisable from the standpoint of economy in copper, even in choke coils, to adopt the terminal disposition rather than to have a few coils for a whole plant.

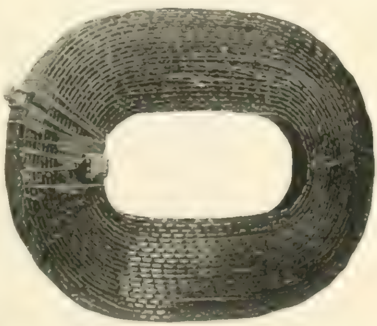

FIG. 14—DETAIL FROM FIG. 13, SHOWING THE VENTILATION OF THE COILS

Further proof of the effectiveness of choke coil design has lately been furnished by a thorough investigation of the value of various types of choke coil protection. Fig. 15 gives a diagram of the connections employed.

The transformer used for the test has duplicate taps brought out from a number of symmetrically arranged points of the winding. By means of these taps connection can be made to a measur-

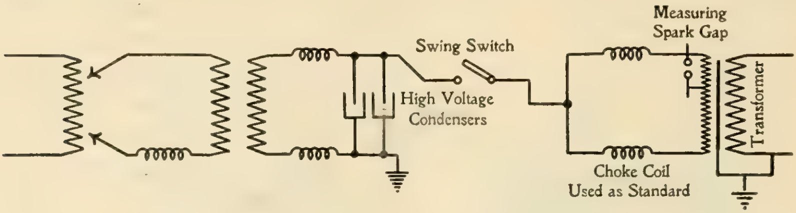

FIG. 15—DIAGRAM OF CONNECTIONS EMPLOYED FOR DETERMINING THE VALUE OF CHOKE COIL PROTECTION

ing spark gap on which the magnitude of the disturbance can be closely determined. On one side of the transformer a standard

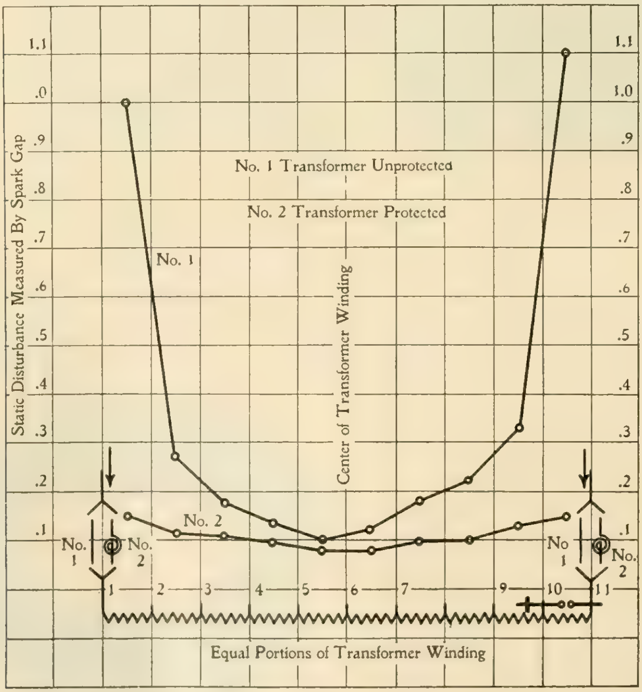

FIG. 16—CURVE SHOWING PROTECTION AFFORDED BY CHOKE COILS

coil may be placed and the readings taken on this side of the winding contrasted with those secured after the introduction of a test coil on the other side through the use of the duplicate taps. The

value of choke coil protection over no protection can readily be demonstrated by measuring first with and then without coils as shown in Fig. 16.

In order to make sure that the maximum disturbance has been measured a number of readings are taken from any given loop, often as many as fifty, all readings on a test being derived from the same number. This is secured by means of a swing switch which unloads the static charge into the apparatus. A reference to the sketch of apparatus used for the equivalent spark gap method of testing will show its applicability to this end.

ONTARIO POWER TRANSFORMER

THE frontispiece shows a view of a 3 000 kw, 62 000 volt transformer to be installed at the generating plant of the Ontario Power Company, Niagara Falls, Ont. It is one of twelve raising transformers of the largest size yet built and will be used to supply a transmission system which will ultimately distribute about 200 000 hp through western and central New York.

Three transformers are connected with their low tension windings in delta and their high tension windings in star to change from the generator voltage of 12 000 to the line voltage of 62 000.

The transformer, aside from its size, possesses many novel mechanical and electrical features. The case is oil and air tight and is made to withstand an internal pressure of 150 lbs. per sq. in., which has required a new form of high tension terminal and bushing. The full load efficiency of the transformer is over 98.7 per cent. and the regulation at the power factor of transmission is within 1.5 per cent.

The total weight of the transformer is over 95 000 lbs., the total height sixteen feet, and the diameter nine feet six inches.

INSULATION TESTING II*

C. E. SKINNER

(5) MEASUREMENT OF THE TESTING VOLTAGE

The following methods are used for measuring the testing voltage:

(*a*) *By ratio.* In the lower voltage work, where the static capacity of the apparatus to be tested is small and extreme accuracy is not necessary, the simplest method is to measure the primary voltage and multiply by the ratio of transformation. In making a large number of tests, as is required in the manufacture of electrical apparatus, it is usually sufficient to connect the testing set to mains carrying a known difference of potential and assume that the results will be sufficiently close to ratio. This method will be found inaccurate when the electrostatic capacity of the apparatus under test is large, a rise of the voltage in the testing circuit usually resulting when the output of the testing transformer is sufficient to carry the current without serious drop in voltage. Even when the voltage is measured directly in the testing circuit, a voltmeter in the low-tension circuit will be found a great convenience to check the readings.

(*b*) *By voltmeter readings in the high-tension circuit.* The reading may be taken across the whole or any part of the high-tension windings. Direct-reading voltmeters of the current-operated type used in series with a non-inductive resistance may be employed for this purpose. The chief advantage of this method is the ease of calibration, and it has the further advantage that the voltmeter may be an ordinary instrument supplied with the necessary series resistance. It has the disadvantages that the charging current of the voltmeter resistance may lead to inaccuracies; the voltmeter itself must be covered by a metal case which is connected to one terminal of the voltmeter to prevent the static charge from affecting the needle; and the resistance on very high voltages consumes a large amount of power; also, the resistance is clumsy and difficult to insulate.

A static voltmeter in the testing circuit is theoretically the ideal method of measuring the testing voltage. Unfortunately,

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*Continued from September Journal, p. 550.

static voltmeters reading up to the highest voltages required in testing work are not available. Instruments of this class which the writer has been able to test are either inaccurate or are so delicate in their adjustments that they are constantly getting out of order, also the scale is short, and the range of reading is small. No thoroughly reliable instrument reading up to 100 000 volts under all conditions of service has as yet been placed on the market.

(*c*) *By spark gap in the high-tension circuit.* The committee of the American Institute of Electrical Engineers appointed to consider this matter has recommended the determination of the testing voltage for any given piece of apparatus by the use of a spark gap in the high-tension circuit, this spark gap to consist of sharp needles, the distances for various voltages being given. This method has many disadvantages and few advantages. The testing voltage cannot be determined until the instant of breakdown of the gap, when the test must be discontinued. The voltage measurements are very unreliable unless especially safeguarded by an elaborate set of shields, and there is much controversy as to the actual distances which represent given voltages. When used in the testing circuit with very high voltages, the disruptive discharge caused by the breaking down of the gap may cause serious damage, either to the testing transformer or to the apparatus under test, due to the momentary rise of potential across the outer windings when the spark gap breaks down. In testing transformers and generators the spark gap should always be used in series with a very high resistance or a powerful choke coil.

(*d*) *By special voltmeter windings.* In special cases windings are placed on the transformer in such a way as to give more nearly the actual ratio of transformation that can be obtained by measuring the voltage of the primary circuit. This is really a ratio method, and is somewhat more accurate than measurements across the primary circuit, on account of the position in which the winding is placed and the freedom from drop due to load which is experienced in the regular ratio method.

(*e*) *By voltmeter transformer.* It is possible to use a step-down transformer in the high-tension circuit connected to a voltmeter. This is a satisfactory method where the voltage is low and the output of the testing transformer sufficient to supply the voltmeter transformer losses, etc. It becomes a very expensive method with very high voltages, for the reason that the voltmeter transformer is very difficult to wind and insulate for such small capac-

ities. For a 60 000-volt voltmeter transformer the mechanical requirements are such that the transformer when built will have a capacity of 15 to 20 kilowatts, while the voltmeter takes only from 15 to 20 watts. The writer is familiar with voltmeter transformers where the losses in the transformer itself were many times the rated output of the transformer.

(6) PROVISION FOR LOCATING FAULTS

In many tests it is very desirable to be able to locate faults that occur under test. One of the most satisfactory methods in the testing of electrical machinery is to hold the testing current a sufficient length of time to produce burning of the insulation at the point of fault, this being located by the smoke which issues from the point. This is particularly true in the testing of windings of transformers and machines. For this purpose a resistance or inductance in some part of the circuit of the testing apparatus is very satisfactory. A convenient method is to provide such a resistance or inductance in parallel with a fuse or circuit-breaker in the primary of the testing transformer, this fuse or circuit-breaker being so adjusted that it will carry the normal testing current until the fault occurs, the increase in current due to the breakdown blowing the fuse or circuit-breaker and thus throwing the resistance or inductance in series with the transformer. The resistance can be so adjusted that approximately normal current will flow through high-tension windings of the transformer, and when this is done the burning may continue for any desired length of time without injury to any part of the testing apparatus. In the testing of cables it is usually necessary to burn out a breakdown sufficiently to produce a low resistance fault, which may then be located by any of the well-known methods. The arrangement of resistance and circuit-breaker for burning out faults is indicated in several diagrams shown last month.

(7) PORTABILITY OF TESTING APPARATUS

The portability of testing apparatus is entirely a matter of convenience as required by the work to be done. In a large factory it is desirable to have apparatus giving voltages up to 10 000 or 20 000 that can be very quickly moved from one point to another and can be used with the utmost despatch. For testing large machinery or insulating materials this portability is not so essential, as the tests are fewer with more time available, or the material may be

brought to the testing apparatus. For an ordinary power plant it is generally sufficient to have a stationary testing outfit, which may be wired to convenient points in the building. For heavy road work a semi-portable outfit for the higher tension work is desirable, so arranged that it can be shifted from place to place. The portability depends on the size and general construction of the apparatus. The type shown in Figure 3* which gives extreme flexibility as to variation of voltage, variation in the primary source of supply, etc., can be made without difficulty in portable form up to 30-kw capacity.

(8) RATING OF TESTING TRANSFORMERS

Throughout this paper the kilowatt rating of testing transformers has been referred to, and wherever used this refers to the usual method of rating based on rise of temperature when the transformer is carrying the rated load continuously. As a matter of fact, testing transformers are rarely, if ever, used continuously, and usually tests are made only for a very short length of time. The requirement of the American Institute of Electrical Engineers is that the test shall be continued for one minute. As most transformers will carry for short periods several times the amount of current allowable for continuous work, it is obvious that the continuous rating is not a satisfactory basis for testing transformers.

When a testing transformer is to be used for routine cable testing, where the tests are applied for some length of time with but short intervals between tests, the rating may properly be made on the time temperature basis. For nearly all other work the rating can be on the basis of the maximum current that the transformer can deliver for short periods of time. It should be apparent that each class of work will require a special rating, and that there will be wide differences between the different classes.

TESTING METHODS

In the testing of materials, the very greatest variety of physical characteristics will be met with—as fabrics, porcelain, oil, papers, and almost every conceivable combination of materials. So diverse are the kinds that only general rules can be laid down covering the methods to be followed.

To insure uniformity of results (and the best results rarely agree closely) tests on similar products should of course always

*See *The Electric Journal*, Vol. II., p. 540.

be made in the same manner, and it is always desirable to check tests on new materials with results of tests on materials of the same class whose qualities are known, the check tests being made at the same time and under the same conditions. The contact terminals should be of the same size and shape. The rate of application of the voltage and the total time of making the test should be the same. The method of measurement should be the same. The constants of the testing circuit—frequency, wave form, etc., should always be the same for comparative purposes.

For sheet material, metal terminals with the edges well rounded to prevent concentration of electrostatic flux at the sharp edges, should be used. When the sheets are small and the test voltage low, circular terminals with an area of approximately one square inch with edges rounded to a 0.25-inch radius tangent to the testing surface will give good results. Many tests are made between terminals having spherical contacts, 0.5-inch to one-inch hemispheres turned on the ends of rods being employed. For irregularly shaped solids, such as porcelain, the conditions of service should be simulated as far as possible. For example, a line insulator should have a contact similar to that of the line and tie wires, and test should be made to a metal pin, under the assumption that the pin is wet and therefore a conductor; or test may be made by inverting the insulator in a salt-water bath and filling the pin hole with the same solution. For liquids, the oil testing device described in a paper by the writer on *Oil for Insulating Purposes,** read before this association last year, will be found satisfactory.

High temperatures may be produced in insulating material by the I^2R losses when the material has low insulation resistance. In materials such as marble and slate, which may have low insulation resistance due to moisture, the heat caused by the I^2R losses may dry the material to such an extent that the insulating quality is increased as the test proceeds. With fibrous materials the reverse is usually true, as carbonization takes place before the drying-out process is complete.

In testing solids the effect of heat due to dielectric losses is an important factor in the results, particularly when large contacts are used and tests are long continued. For a fuller discussion of this point, see paper by the writer entitled *Energy Loss in Com-*

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*See "Transformer Oil."—C. E. Skinner, *The Electric Club Journal,* Vol. I., p. 227.

mercial Insulating Materials When Subjected to High Potential Stress, Proceedings of the American Institute of Electrical Engineers, Vol. 19, page 1050. The heat generated weakens the insulation and breakdown results at a lower voltage than when the time occupied in making the test is short. This will be found particularly true of materials like glass, treated cloth, mica, etc. Most insulating materials in the solid form decrease in insulation strength as the temperature is raised, and therefore the temperature at which tests are made should be held as nearly the same for different tests as possible.

Aside from the heating effects noted above, the method of applying the voltage when testing samples of material is not of much importance, whether by steps, by gradual rise, or by the application of full voltage at once, where the test is a predetermined amount and the testing voltage not high—say not over 20 000 or 25 000 volts. It is important, for purposes of comparison, that the same method be used for different samples of material of the same general class. As the actual breaking-down point is desired in most tests on material, the voltage must be applied in predetermined steps, or the rate of increase must be such that voltmeter readings can be taken and the exact point of breakdown determined. For low-voltage tests the step-by-step method, keeping the primary voltage constant and determining the test voltage by ratio, is recommended for rapid work. For higher voltages, say above 20 000 or 25 000, the slow increase of voltage, either by steps without opening the circuit or by smooth increments, as by control of the alternator field, gives better results. The voltage may be read by ratio, or by a static or direct-reading voltmeter in the high-tension circuit. No single test should be taken as an index of the dielectric strength of any material, but the average and lowest of many tests should be considered.

In the testing of dynamos, motors, transformers, cables, etc., the static capacity of the apparatus under test becomes of more importance, especially with the higher-voltage tests, requiring larger testing apparatus and greater care in the application of the testing voltage. There will also be greater tendency to variation in the testing circuit due to rise of potential on large static capacity, drop due to overloaded transformers, etc., than with samples of material, hence the ratio method of measuring the voltage is less satisfactory than in material testing.

Furthermore, tests on finished apparatus are usually not made to determine the ultimate breaking-down strength, but to determine whether or not the insulation as a whole will stand a certain predetermined test, allowing a factor of safety over the working voltage, just as a boiler is tested with a certain excess pressure for the same reason. It is good practice in manufacturing work to test each part as it is finished, as well as the completed apparatus, in order that any defective workmanship or material may be discovered before the parts are finally assembled. The user of the apparatus is concerned only with the dielectric strength of the apparatus as a whole, while the manufacturer is concerned with each individual part as well as the completed product. It is customary in manufacturing work to find the ultimate break-down strength for each class or type of apparatus, by actual break-down tests on individual pieces, this showing the weakest point and the necessity for any change in material or design if the ultimate strength is not sufficiently high.

In testing electrical machinery during the course of manufacture it is customary to grade the tests from higher to lower values as the apparatus nears completion. By this method any given test is lower than the preceding, and small variations in the voltage of the line supplying the testing circuit will not cause any difficulty.

Transformers are sometimes tested by their own voltage, this giving a plan different from any of those described above and requiring no testing transformer. In such tests, one side of the high-tension winding is connected to the low-tension and the iron, and then the transformer operated at a potential sufficiently above the normal to give the necessary test voltage. The other side of the high-tension winding is then connected in the same way, and the test repeated. Attention should be called to the fact that in this test the middle part of the winding receives but half the total test voltage to ground and low-tension coils, there being a uniform grading of test voltage along the winding from the middle point to the outer ends.

In making dielectric tests on completed apparatus, the condition of the apparatus at the time of test is a point which should always be considered with reference to the test. Insulation resistance measurements usually give some indication of the condition of the apparatus with reference to dirt and moisture. A high insulation resistance test, however, does not necessarily indicate that the dielectric strength will be high, but a low insulation resistance

test usually indicates a low dielectric test, particularly if the dielectric test is long continued.*

Long continued tests on apparatus such as dynamos and motors are considered very inadvisable, unless the voltage of test is very much below the ultimate breaking down strength and the condition of the apparatus with respect to moisture is perfect, as such long continued tests are liable to produce incipient burning at points within the insulation, which may not be discovered by the test.

In the making of insulation tests of all kinds the factor of personal danger should always be considered. The lowest maximum voltage given in the table of testing apparatus earlier in this paper is considerably more than is necessary to cause death. Special care should be taken to protect not only the operator but others in the neighborhood of the apparatus under test. If it is necessary to handle the live terminals at all, only one should be handled at one time, and it should be insulated beyond any possibility of the testing set being grounded whenever possible. Where a regulating transformer is used the intermediate circuit should always be grounded, as well as the frame and case of the transformer. As this circuit is entirely independent of both the source of supply and the testing circuit it can be grounded without affecting either. For this reason the regulating transformer with primary and secondary is preferable to the auto or single coil transformer, although the latter is cheaper for a given output. A very excellent safeguard for the operator is effected by the use of a main switch which is automatically opened and held open by a spring. With this device the operator must hold the switch closed as long as the test is continued.

The necessity for these precautions is so obvious that it would seem hardly necessary to call attention to them here, but the writer has noted the indifference and carelessness customary with those who habitually handle testing apparatus of this class, and it is the purpose of this paragraph to warn such that it is hardly possible for the same individual to make more than one mistake.

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*See "Transformer Insulation." — O. B. Moore, *The Electric Journal*, Vol. II., p. 333.

THE KATHODE RAY OSCILLOGRAPH

ROBERT RANKIN

THE increasing study of wave forms resulting from the use of the oscillograph, is leading to a rational conception of alternating current phenomena which is of inestimable value both to the designer and to the operator of electrical machinery. It is the purpose of the writer to describe some improvements in a familar type of oscillograph which have made it for many classes of work an inexpensive and reliable curve tracer.

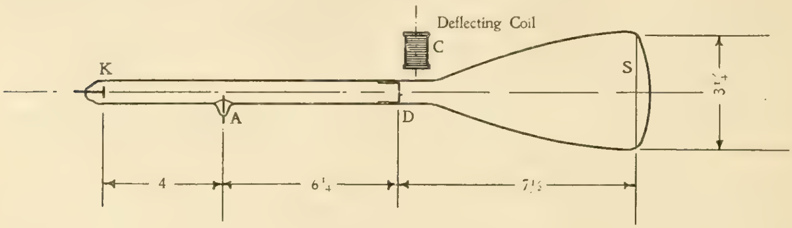

FIG. I

ORIGINAL FORM OF TUBE

The well-known susceptibility of kathode rays to deflection by magnetic lines, was first made of practical use in 1897 by Braun.* The vacuum tube used by him for generating the rays is shown in Fig. 1.

K is the kathode, a thin plate of aluminum, *A*, the anode and *D* a diaphragm of the same metal. The latter fits closely the walls of the tube and has at its centre an opening of about 1/12 of an inch in diameter. *S* is a mica screen covered with calcium sulphide, which fluoresces powerfully when impinged upon by the rays. If a sufficient potential be established between *K* and *A*, kathode rays are generated which proceed directly from the former down the tube toward *D*. The diaphragm permits only a small pencil of rays to pass it and this pencil strikes the screen *S*, producing a small spot of light. By placing a coil, *C*, with its axis perpendicular to the path of the rays as shown, and by sending alternating current through this coil, the spot is deflected in a direction perpendicular to both the path of the rays and the axis of the coil. If the flux set up by the current is not influenced by the presence of iron, its instantaneous value and hence the instantaneous value of the deflec-

*Braun, Weid. Annal. 60, 1897, p. 552.

tion will be proportional to the corresponding current values. The apparently continuous line thus produced on the screen will therefore, if viewed in a revolving mirror, give an exact representation of the wave of alternating current passing through the coil.

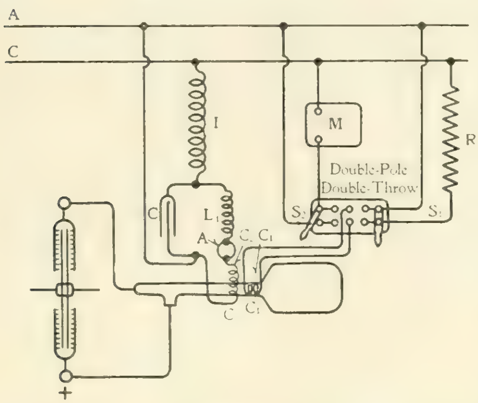

FIG. 2

Braun's first studies were limited mostly to the wave forms of induction coils and since the figures which he produced were small, from .5 to .75 inches in height, the results had little quantitative value.

METHODS FOR OBTAINING OPEN CARDS

In 1900 Professor H. J. Ryan became interested in the kathode ray tube and induced the German glass blower Müller-Uri to make after a larger design a tube which had a diameter of screen of about five inches.* To Professor Ryan belongs the credit for first setting up and making use of the tube in practical engineering research. He added to the unknown wave as deflected on the screen by a single pair of coils, a known wave caused by a pure sine wave current led through a second pair of coils at right angles to the first. The sine wave current being taken from the same source as was the unknown wave, had the fundamental frequency of the latter but was caused to differ from it in phase. The resultant motion upon the screen gave an open card from which the known wave might be separated to find the unknown. The method of obtaining and using the known sine wave may be understood from an inspection of the following diagram, Fig. 2.

L is an impedance consisting of practically pure inductance of an amount sufficient to control the flow of current from the lines *A* and *C*. This exciting current is led through L_1, a second inductance, and *C*, a capacity arranged in parallel. In series with L_1, is also placed an ammeter *A*, and one set of deflecting coils C_2. The cir-

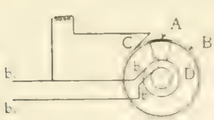

FIG. 3

*Ryan, Trans. A. I. E. E., July 2, 1903; Trans. A. I. E. E., Feb. 20, 1904

cuit L_1, is adjusted with reference to C for approximate resonance of the fundamental, the usual values giving a current in the local parallel circuit of about five times the exciting current through L.

We have then the following damping or screening effect to produce a wave which for all practical purposes is of purely sine form.

L offers to the third harmonic three times the inductive reactance that it offers the first. L_1 in turn offers three times the inductive reactance to the third harmonic as to the first, while C offers one-third the reactance to the third as to the first. We have

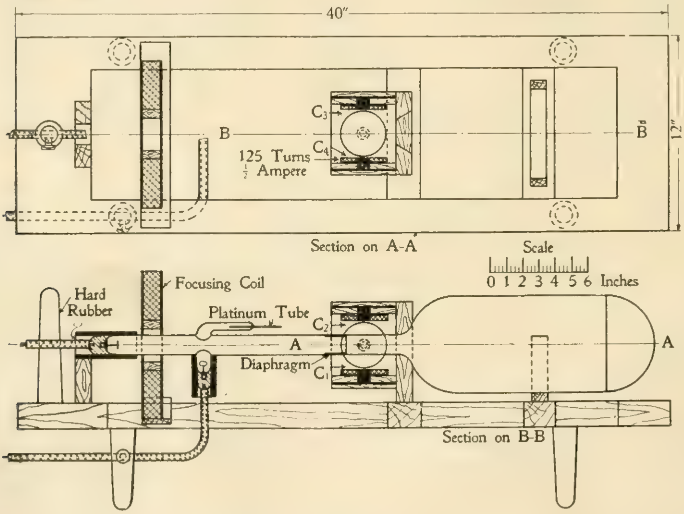

FIG. 4

therefore a factor of $3 \times 3 \times 3 = 27$ tending to reduce the third harmonic as compared to the first in circuit L_1. But this circuit also has been adjusted for approximate resonance of the fundamental and we hence introduce another factor of five, making the total reduction of the third over the fundamental, of 135 to 1. If we assume a wave in which the third harmonic had a value equal to 30 per cent. of the first, we will have a component remaining in the screened wave of $.30 \div 135$, or about 0.20 of one per cent. of the fundamental. Similarly the reduction factor for the fifth harmonic will be $5 \times 5 \times 5 \times 5 = 625$. If desired, the screening process may be carried still further but the above arrangement is usually suffi-

cient. It is necessary that the inductance coils used, L and L_1, have open magnetic circuits and that the saturation m.m.f.s utilized by the iron cores be small compared with those used by the air cores in the magnetic circuit of L_1.

The coils C_1 of Fig. 2 carrying the unknown wave form, the switch S furnishing a means of sending through these coils the unknown current due to pure resistance R, or a current wave which may be obtained through some apparatus M.

To obtain cards on the screen direct in rectangular co-ordinates Zenneck* has made use of the device shown diagrammatically in Fig. 3. B is a band of resistance metal laid over the drum D, its ends being separated by an insulation strip A. The terminals of B are brought out to slip rings on the shaft, through which a continuous current may be sent by means of brushes bb. A third

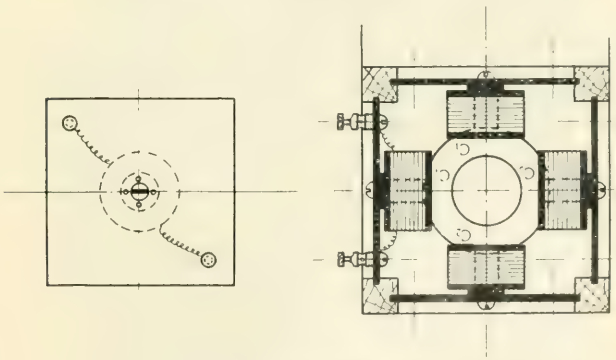

FIG. 5 DEFLECTING COILS

brush C presses directly upon the band B. A shunt circuit from C and one brush b is led through a pair of deflecting coils. With D stationary and a constant current in B the current in the shunt circuit will have a value dependent upon the relation of the brush C to the end of B. With the drum revolving at a uniform rate, the current will increase continually in proportion to the distance displacement, up to a maximum value whence it will return to zero and repeat. This will tend to spread the unknown wave on the screen in the familiar form of rectangular co-ordinates. If the drum be caused to rotate synchronously with the source of supply

*Zenneck, Drude Annal., Vol. 69, 1899, p. 838.

to be analyzed we shall have the figure perfectly stationary upon the screen.

DEFLECTING COILS

The deflecting coils may be designed to carry any desired current and in this respect the kathode ray oscillograph holds a decided advantage over other types. A further advantage lies in the fact that a single calibration of any set of coils with reference to the sine wave coils, is sufficient for all time, every card thereafter being read in terms of a standard ammeter placed in the sine wave circuit.

These coils have however a measurable coefficient of self-in-

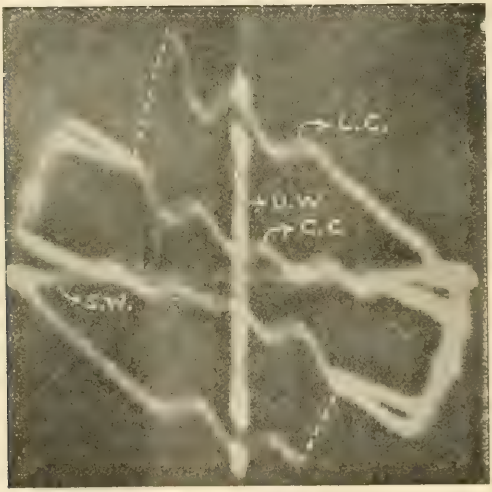

FIG. 6

duction. With ordinary frequencies (up to 133 cycles with the usual accompanying harmonics) the inductance causes no appreciable distortion of the e.m.f. wave on account of the comparatively high amount of resistance used in reducing the current for deflection.

For great accuracy, however, the waves may be obtained, in two ways.

1st. The curve may be taken by the usual method and corrected for the known and constant coefficient of the coils. A convenient aid in this correction consists in sending the e.m.f. wave through a condenser, which exaggerates all the higher harmonics

and gives an easy means of determining which are present. The curve may then be analyzed and corrected in the usual way.

ELECTROSTATIC DEFLECTION *

A second method for obtaining very accurate voltage curves depends upon the fact that the kathode rays are deflected by an electrostatic field in amount directly proportional to the instantaneous strengths of the latter. By mounting condenser plates on either side of the tube at the diaphragm and by impressing an e.m.f. we are able to get the true wave form. This method has been adopted for the study of very high frequency currents.

GENERATION OF THE RAY

For the generation of the kathode rays the electrostatic machine is found to be the most satisfactory source of excitation. Use has been made of induction coils and even of a high tension transformer operating at 200 cycles. In the latter two cases how-

FIG. 7

ever, the intermittency of the rays gives an unsatisfactory card. We have obtained excellent results with a 12 plate, 17 inch motor-driven Wimhurst machine, and also with a two plate 30 inch Holtz machine. Cards may be obtained from the ordinary forms of two plate hand driven influence machines found in all laboratory equipments. It is advisable however to have these driven at constant speed.

In the continuous use of the tubes as first put upon the market, much trouble arose from the tube vacuum which increased rapidly with the passage of the electric discharge. The increased voltage required to establish the discharge caused leakage around the tube terminals and a correspondingly unsteady spot upon the screen. It

*Zenneck, Drude Annal., Vol. 69, 1899, p. 838.

was found that an insulating jacket placed over the tube between anode and kathode had a steadying influence but this was found to exist over a comparatively short range. Several devices were tried for regulating the vacuum itself and the tube shown in Fig. 4 is equipped with the most successful of these. This consists of a hollow platinum tube cemented into a small chamber leading from the neck of the kathode tube as shown. The platinum tube is closed only at its outer end, thus forming a small chamber connected with the main tube. If this platinum be heated to dull redness it permits a small quantity of hydrogen to pass from the heating flame through and into the main tube, thus reducing the vacuum and therefore the voltage required to establish the rays. This process is simple and very effective, the vacuum being re-

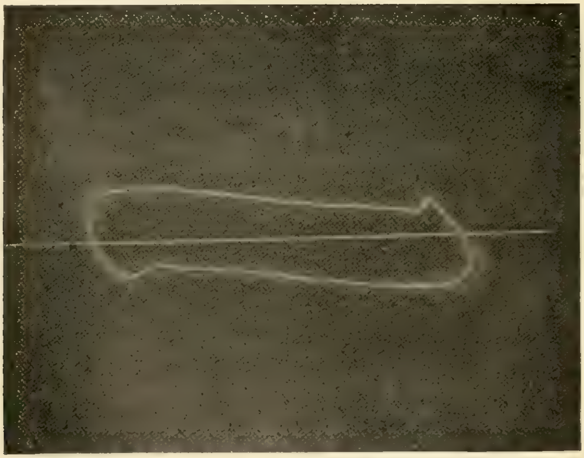

FIG. 8

duced by the necessary amount in a few seconds. It may be noted here, however, that if the gas pressure in the tube be raised so high as to prevent the establishment of kathode rays, no amount of discharge will restore the operating condition.

FOCUSING COIL

The writer in the past year has employed another method in conjunction with the above, for controlling the voltage at which the discharge is generated and for producing a much steadier and more intense spot of light on the screen. This consists of a coil carrying direct current, placed axially over the tube between anode and

kathode as shown in Fig. 4. Briefly the effect of such a coil is as follows:

1.* To reduce the voltage required to maintain the tube discharge.

2. To secure a certain focusing action which directs more of the rays through the aperture in the diaphragm, thus giving a more intense spot of light.

3. To give a means of varying between limits the velocity of the ray and hence its susceptibility to deflection thus giving a means for varying the sensitiveness of the oscillograph.

It was also found that if the field due to the focusing coil be made very intense, that the tube vacuum increased much more rapidly than under ordinary conditions. This action was dependent upon the presence of kathode rays. In one case where the vacuum had been brought so low by overheating of the platinum tube, as to leave only a faint ray hardly visible as a spot upon the screen, the magnetic field acting upon the discharge for one hour produced a marked increase in vacuum and a corresponding improvement in the tube operation.

With the strength of the field ordinarily used in focusing, it has not been found that the vacuum rises more rapidly than under ordinary conditions.

RECORDING OF CARDS

The recording of cards taken on the screen has been done in several ways.

1st. By tracing them on smoked glass from a fixed view point just behind the screen.

2nd. By plotting point by point from cross-section lines drawn upon the screen itself.

3rd. By photographing the card direct.

All these methods have until recently required a frequently recurring wave form and although as will be presently shown, improvements in the last method have been made, the kathode ray oscillograph will probably be little used for recording instantaneous waves.

The time of photographic exposure depends upon the intensity

*Birkeland (Compte Rendu, 1st Semester, 1898, p. 558) has reported all of these phenomena with reference to the ordinary straight form of Crookes tube, but so far as known has suggested no practical use of them. A discussion of some experiments along this line conducted by the writer will be found in a forthcoming number of the Physical Review.

of the kathode rays, upon the number of them which pass through the diaphragm, upon the actinic property of light produced by the impingement of the rays on the screen and upon the amount of this light which passes the screen without absorption. This latter item has been a serious drawback in the photographing of cards from the tubes in use at the Cornell laboratory. The screens of these are of a rather thick quality of mica which has been found to absorb the actinic rays to a considerable extent.

Fig. 6 shows one of the earlier forms of card which was taken with a low velocity of ray and which required an exposure of about five minutes. Figs. 7 and 8 were taken with a higher velocity of ray and required an exposure of 10 to 15 seconds. The sharp line

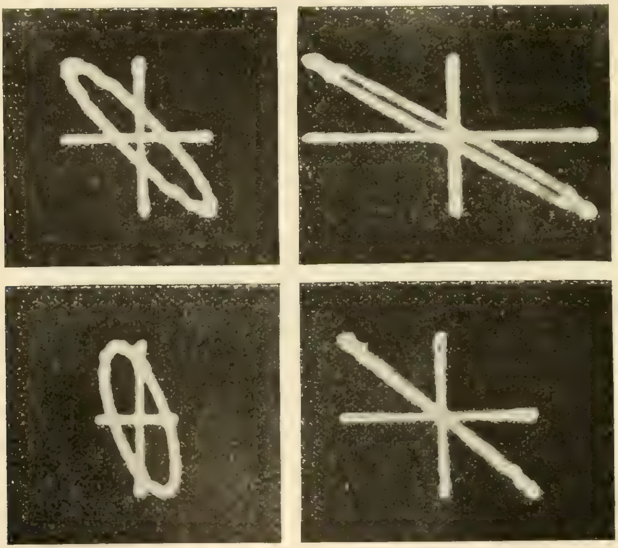

FIG 9

shown in these prints was made by tracing over the impression on the plate itself.

Zenneck* has, however, devised a new form of screen which produces very good results. This consists in the substitution of glass for mica and in the use of calcium wolframat ($CaWO_4$) instead of the CaS usually employed as the fluorescent substance. Some cards taken by Zenneck are reproduced in Fig. 9. They give a very good representation of the appearance to the eye of cards

*Zenneck, Weid. Annal., Vol. 9, 1902, p. 518.

upon the ordinary screen. The photographs of Fig. 9 were taken with exposure varying from one to six seconds according to the strength of the ray.

Fig. 10 shows some instantaneous photographs taken by Wehnelt and Donath.† The small sine wave in the upper part of the card is produced by the vibrations of a tuning fork and serves as the time scale. The actual size of the cards which may be obtained from a Ryan-Braun tube is from $3\frac{1}{2}$ to 4 inches maximum deflection.

USES OF THE KATHODE RAY OSCILLOGRAPH

The kathode ray oscillograph has been used up to the present time chiefly for special investigations and for illustrative work in college laboratories. Its simplicity and ease of operation together with all absence of moving parts make it particularly adapted for experimental instruction, since it can be operated continuously and satisfactorily without the attention of an expert.

Some of the interesting experiments which may be illustrated by the use of this apparatus are as follows:

ROTATING FIELD

This is shown by sending two currents from the same source of e.m.f. through the two sets of deflecting coils, one of these currents being caused to differ in phase from the other by passing through an inductive or capacity circuit. This causes the deflecting spot to rotate in a circular or elliptical path, dependent upon the relative strengths of the two currents. This is shown in Fig. 9. One current alone produces a vertical line, the other a horizontal line. The two together produce a straight line, an ellipse or a circle depending upon their phase difference. In case the waves are not of sine form the higher harmonics are shown as impressed upon the fundamentals. The opposite effects of capacity and inductance upon these higher harmonics may be shown by a combination of the field produced by each of these two forms of reactance and the sine wave as previously described.

The hysteresis loop of iron has been produced in several different ways. The following method devised by Dr. Morris, of Birmingham, for the Duddell oscillograph has been found very convenient. For this the two low pressure windings of any commercial transformer may be used. One of these windings is placed

†Wehnelt, Drude Annal., Vol 69, 1899, p. 861.

in series with a pair of deflecting coils and the normal voltage impressed upon it. The second winding is placed in series with the

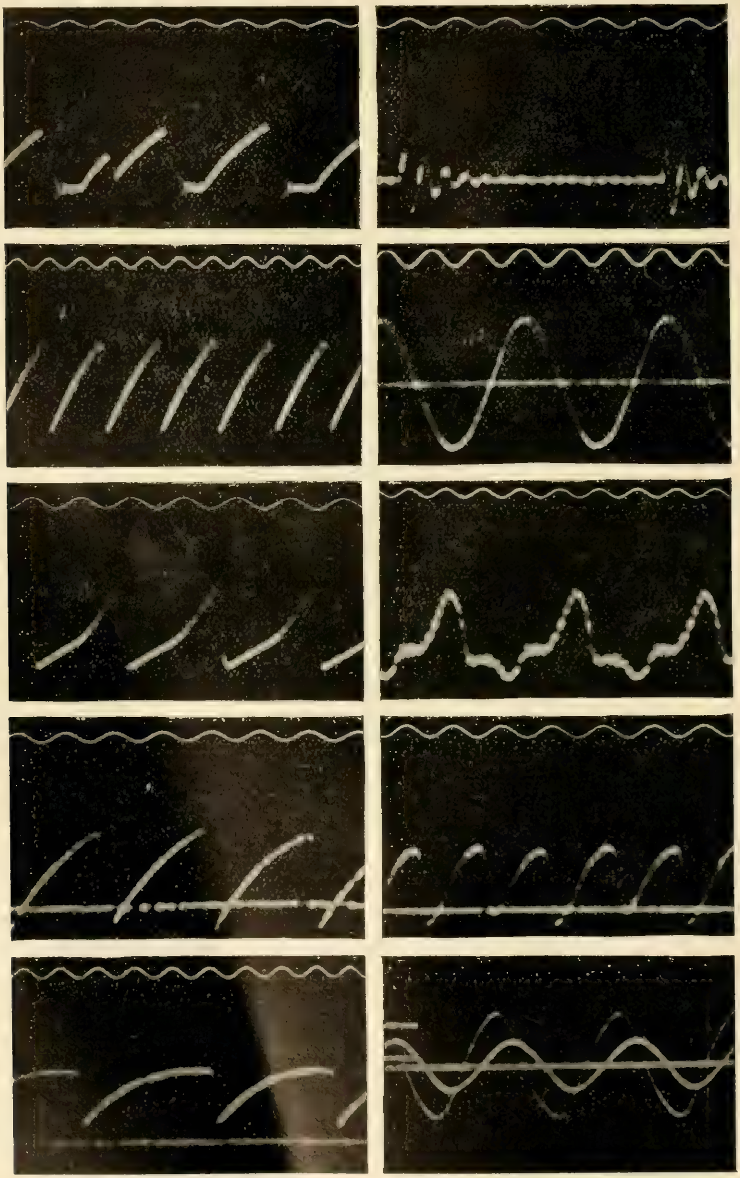

FIG. 10

other set of coils and also with a reactance coil with air core, the resistance of this coil being negligible as compared with its inductive reactance. The exciting current of the first circuit will be proportional to the magnetizing force, while the load current in the inductive circuit will be equal to $L \frac{di}{dt} = \frac{\Phi}{dt}$ That is the load current will be proportional to the instantaneous flux values. The result of the combined motions given the spot by these currents will be the operating hysterysis loop of the transformer.

In the use of the above method with the Duddell instrument, it is necessary to have two vibrating mirrors, the light from one being reflected by a system of prisms and lenses into the other which reflects the hysteresis loop.

Another method for producing the hysteresis loop was devised by Angstrom. In this the sample of iron to be tested is made up in the form of a long core over which a suitable winding is placed. The winding is placed in series with a source of alternating e.m.f. and also with one set of deflecting coils. The core is then placed in such a position that the deflecting spot is influenced by the flux in the iron, the direction of deflection being perpendicular to that induced by the exciting current in the deflecting coils. The resultant motion gives the desired hysteresis card upon the screen. By varying the exciting current this card may be made to assume all the familiar forms of the Ewing cycle up to saturation.

Figs. 7 and 8 are two of the cards taken during Professor Ryan's experiments in high tension losses previously mentioned.

Fig. 7 shows the smooth form of charging current flowing between two highly charged conductors just previous to the formation of corona and Fig. 8 shows the introduction of the energy component which represents the energy loss after leakage begins.

Figs. 4 and 5 show the modern form of tube with the mounting devised and used in the Cornell laboratory. In this form with the improvements already mentioned the apparatus is shortly to be placed on the market by the Leeds and Northrup Company of Philadelphia.

In conclusion, the writer wishes to express his obligation to Professor H. J. Ryan for the use of photographs and for access to data regarding the early work done by him.

HOW TO USE THE SLIDE RULE ON THE WIRE TABLE

Y. SAKAI

HOLD the slide rule upside down with the back scales, *S*, *L* and *T* of the sliding part in view at the right hand end.

On the *L* scale find the number representing the size of the wire whose resistance is desired.

Place this number opposite the index on the other part of the rule.

Turn the rule right side up and the reading on the lower scale of the stationary part opposite the end of the scale on the sliding part is the required resistance.

EXAMPLE—Find the resistance of 1 000 feet of No. 5 B. and S. copper wire.

Place the point 5 of the *L* scale opposite the index. See Fig. 1.

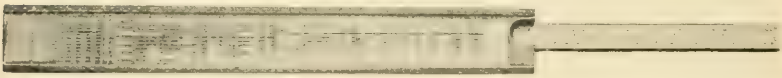

FIG. 1

FIG. 2

Turn the rule over and read the *D* scale opposite the left hand end of the sliding scale *C*. See Fig. 2. The integer result is 3162.

The decimal point can be fixed by remembering that the resistance of No. 10 wire is 1.0 ohm per thousand feet and that the resistance of No. 0 is 0.1 of an ohm. Obviously the resistance of No. 5 is .3162 ohms.

To find the resistance of wires larger than No. 0 and smaller than No. 10, it is only necessary to remember the rule given by Mr. Scott.*

"A wire which is ten sizes larger than another wire has ten times the weight and one-tenth the resistance."

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*See *The Electric Club Journal*, Vol. II., p. 220.

Obviously a wire twenty times larger has one hundred times the weight and one-hundredth of the resistance: For example, to find the resistance of No. 17 wire, find the resistance of No. 7 and multiply it by ten.

EXPLANATION—The fomula, $R=0.1\times 2^{\frac{n}{3}}$ ohms, given by Mr. Pender† may be written:

$$\text{Log } R+1=\tfrac{n}{3}\times 0.30103, \text{ or}$$

$$\text{Log } (10\ R)=\tfrac{n}{10}, \text{ approximately.}$$

That is,

One-tenth of the size number of B. and S. copper wire is approximately the logarithm of ten times the resistance of 1 000 feet of that wire.

The *L* scale on the slide rule represents the decimal portion of the logarithms of the numbers on the *D* scale.

The results derived from the slide rule are for a temperature of about 75 degrees Fahrenheit and will check within one per cent. with the values given in the standard tables for sizes between No. 0000 and No. 16. For the smaller sizes the results will be below, and for the larger sizes the results will be above those given in the tables. For No. 36 the resistance as calculated on the slide rule is about five per cent. low.

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†See *The Electric Club Journal*, Vol II., p. 327.

MODERN PRACTICE IN SWITCHBOARD DESIGN

PART VIII—HIGH TENSION SWITCHBOARDS—POWER CONTROL

H. W. PECK

IT has been noticeable that the switchboard practice already described is such as can be easily standardized with regard to the main features at least. A study of installations of extra high tension and very large capacity reveals the fact that little progress has been made toward a standardization and that there are new

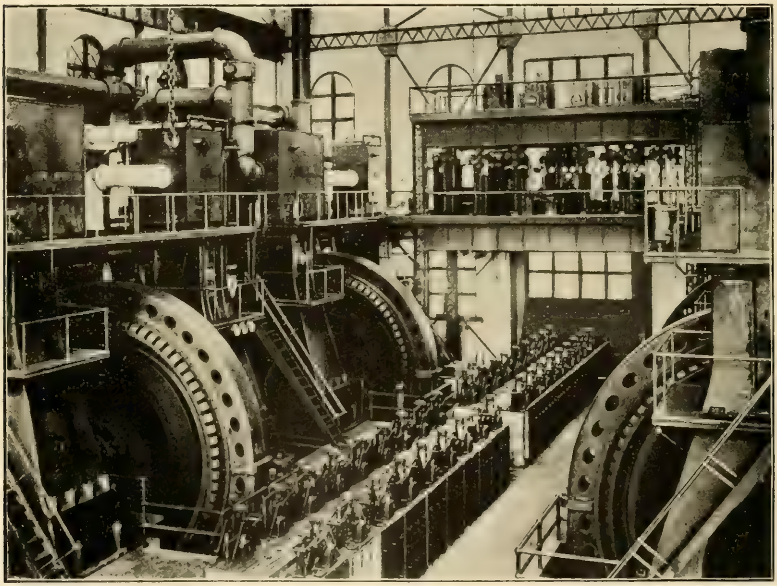


FIG. 27—PRATT STREET POWER STATION

United Railways & Electric Co., Baltimore, Md.
Note switch gear in middle of station and control gallery at end.

solutions of new problems in nearly every case. There are some features which may be described as practice, others as examples or instances.

In the first place high tension installations with an output of more than about 10 000 kw abandon the use of direct hand-operated switches and use an auxiliary power such as air or electricity to open and close the switches. This is required by the size of the switches and the danger of working around the high tension cir-

cuits. It affords, however, many opportunities of which advantage is taken by the engineer.

1. The switches can be set in any place most convenient to the circuits which they control.

2. The main wiring will be direct and simple without crowding.

3. The scheme of connections can be made elaborate without complicating the apparatus or wiring.

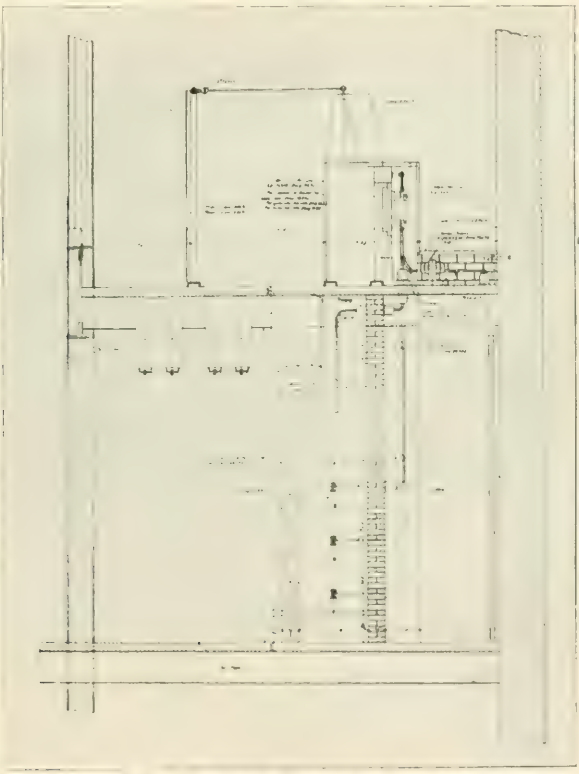


FIG. 28—OIL SWITCH AND BUS BAR STRUCTURE TWO GALLERY ARRANGEMENT

4. All high tension switch gear can be enclosed in fireproof structures.

5. The operator can more easily perform his duties as no great physical effort is necessary and the control apparatus can be located in a small space, easily observed and manipulated.

6. There is no danger to the operator as only low tension

circuits are brought to the control board and the operator is not liable to touch even these.

7. In case of accident in the main circuits the operator is in a safe position where he is not liable to become confused and whence he can disconnect the disabled part without danger.

The switch gear, together with the bus bars, are usually located in such relation to the generators and feeder lines as to obtain short wiring with least exposure and no crossing except when well separated. It may be in the middle of the station between two rows of

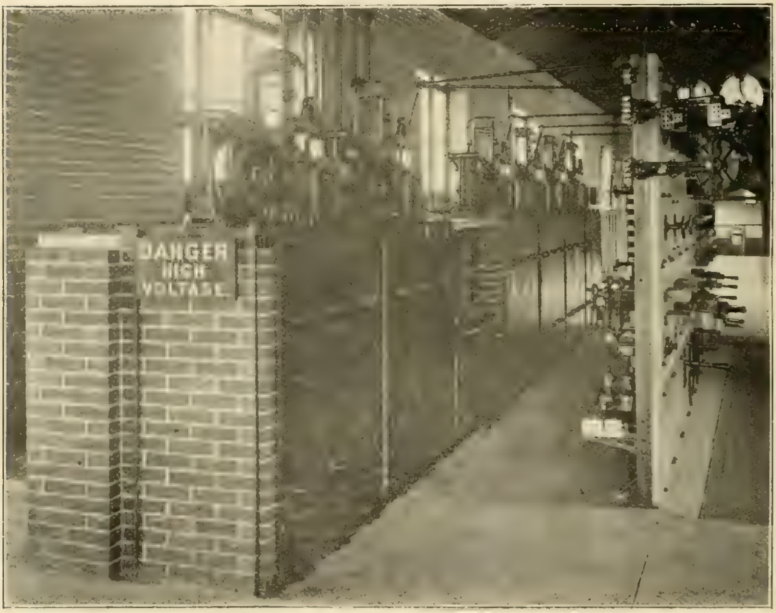


FIG. 29—SWITCHBOARD AND OIL SWITCH GALLERY,
Louisville Railway Co., Louisville, Ky.

generators as shown in Fig. 27. It may be along one side of the station in a row parallel to the generators, opposite the boiler room and away from the steam piping; it may be across the end of the station.

In the first case the generator wiring is short and direct; the bus bars and feeder conduit are on a gallery below the switches in a very compact arrangement but the high tension apparatus is not well separated from the rest of the station equipment. With the other arrangements this objection does not hold but a greater

amount of wiring is usually required. The structure along the side of the building is convenient and allows plenty of room lengthwise, usually more than enough with consequent waste of space and expensive masonry. The structure is more compact at the end of the station but requires more galleries to make a suitable arrangement.

Fig. 28 shows a very good arrangement for a simple equipment. There is one set of bus bars supported on porcelain pillars which are mounted on soapstone shelves. The leads pass through heavy porcelain floor tubes in the rear wall and then up between

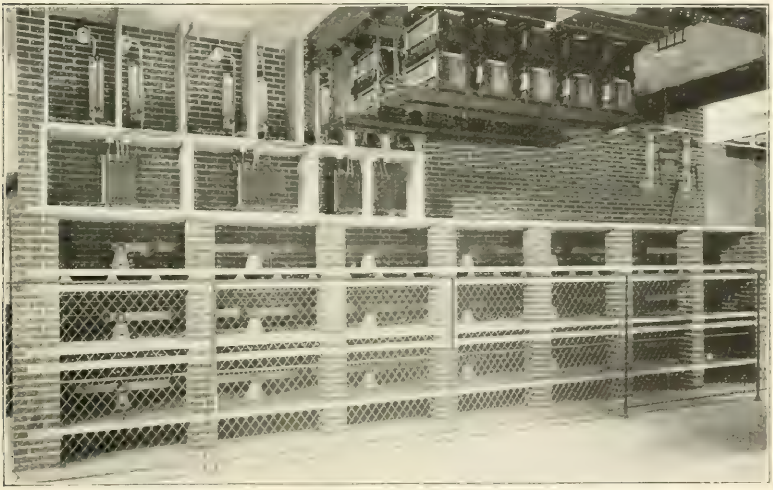


FIG. 30—BUS BAR AND INSTRUMENT TRANSFORMER STRUCTURE AND ALTERNATOR FIELD RHEOSTAT MOUNTING
Louisville Railway Co., Louisville, Ky.

barriers to the knife disconnecting swiches which are mounted in the oil switch cells just below the terminals. This is a very accessible and convenient place for these switches. The leads to the generators and feeders are taken under a false floor where the series transformers are connected in the circuit. The shunt transformers and the fuses protecting the high tension side are located in soapstone cells just above the bus bars. The switchboard controlling the exciters, alternators, and feeders is at the front of the gallery overlooking the engine room. The field resistance of the alternators are suspended from the gallery floor beams below the face-plates, which are on the switchboard. Fig. 29 shows a pic-

ture of this gallery and Fig. 30 shows the bus bar structure and apparatus on the engine room floor.

The cross-section view of a four-gallery arrangement is shown in Fig. 31. The generator leads are carried in ducts up the back of the supporting column to the top gallery *C*, where there is a false floor allowing space for the main and control wires to be carefully and safely installed. The series transformers are located in the back of the oil switch cells and are the first pieces of apparatus

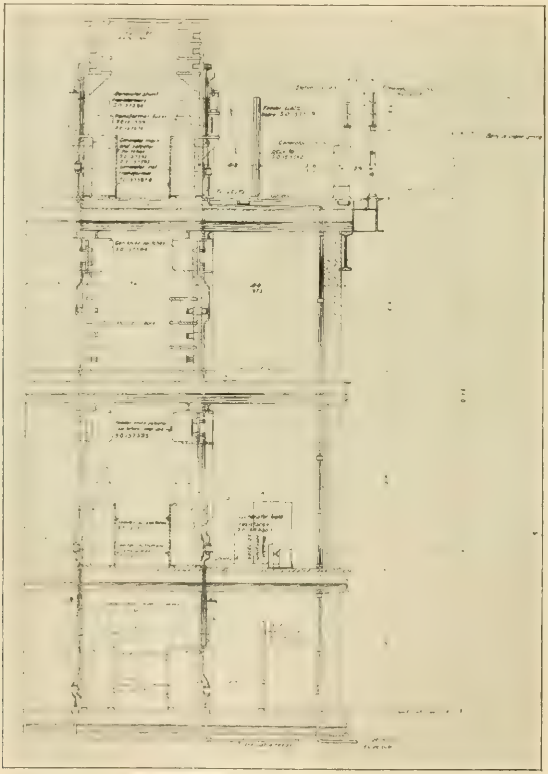


FIG. 31—OIL SWITCH AND BUS BAR STRUCTURE. FOUR GALLERY ARRANGEMENT

in the circuit. Next is the main oil switch whence the leads go up to the auxiliary bus bars connecting the main with the two selector oil switches which are on either side of it. These switches are electrically interlocked with each other. Immediately below the selector switches are knife disconnecting switches operated from gallery *B*. The leads from one of each pair of selector switches

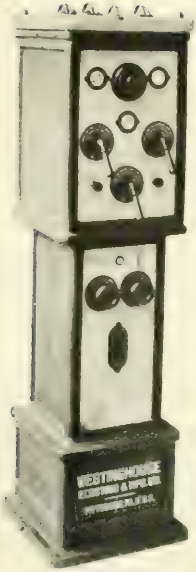


FIG. 32 — GENERATOR CONTROL PEDESTAL

cross below the floor to the line of the other structure. The two sets of bus bars face each other on gallery *B* with passage ways of ample size as are on all of the galleries.

There is a false floor on a part of gallery *B* also under which the feeder lines cross from either set of bus bars to the selector knife switches on gallery a. These switches are mechanically interlocked so that the line cannot be thrown on both bus bars at once. On gallery *A* and the engine room floor are two sets of oil switches in series, also the series and shunt transformers for instruments and the automatic operation of the switches. Upon the engine room floor in front of the high tension switch structure is the panel switch board for the control of the exciters, the alternator fields and the station lighting and auxiliary circuits. The alternator field rheostats with motor driven face plates are located on gallery *A* just above the exciter board.

FIG. 33
GENERATOR INSTRUMENT POST

The high tension control apparatus is on gallery *C*. For each alternator there is a control pedestal and an instrument post as shown in Figs. 32 and 33. The instrument posts are at the edge of the gallery supporting the hand rail and about five feet apart. The pedestals are directly in front of the posts so that the operator has a good view of the instruments or can look between

the pedestal and post to the engine room. Upon the upper section of the pedestal are the controllers and indicators for the three oil switches, a voltmeter plug and receptacle and two synchronizing plug receptacles. Upon the lower panel are controllers for motor-driven engine governor and field rheostat, a double push switch for the field switch, and a push button for signalling to the engineer. Upon the top of the pedestal are four signal lamps.

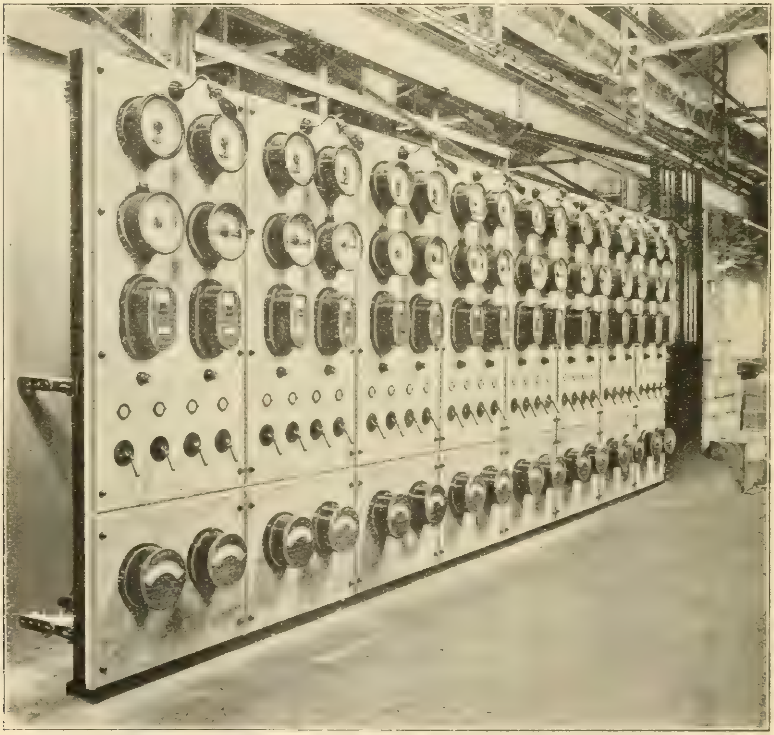


FIG. 34—CONTROL AND INSTRUMENT BOARD FOR 16 HIGH-TENSION FEEDERS
Union Electric Light and Power Co., St. Louis, Mo.

The instrument posts may have arrangements for any number of meters that are required. The pedestals also may be of different size and have a different arrangement of apparatus. The combination of the two for the control of one machine makes a very convenient and pleasing equipment.

Referring again to Fig. 31 the feeder control board is seen to be located just back from the pedestals facing the edge of the gal-

lery so that the operator has the control of the whole high tension apparatus in a space which is small and very convenient. A part of the feeder board is shown in Fig. 34, which shows the small space required for the control of sixteen circuits.

Instead of having separate pedestals for each generator control, a bench board or control desk with one section for each machine circuit is frequently used. Such a desk is shown in Fig. 35. The instruments are then usually mounted upon panels supported above and beyond the desk so that the operator can have a good view of the engine room.

It is evident that the station design and the switchboard design are intimately connected where this type of board is used and that they must be worked out together to obtain satisfactory results. With the position of the switchboard structure in the building determined, the details of that part of the building, iron and brickwork, are dependent upon the switchboard design. While economy of space and cost of structure must be kept in mind, the extreme importance and the very hard service required of the switch gear must make safety and reliability of paramount importance, and must demand the most careful consideration of the switchboard requirements throughout the station design.

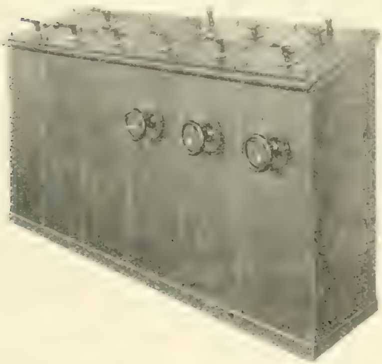


FIG. 35 GENERATOR CONTROL DESK

FACTORY TESTING OF ELECTRICAL MACHINERY—XXI

R. E. WORKMAN

INDUCTION MOTORS – Continued

(c) POWER CURVES CALCULATED FROM SPECIAL DIAGRAMS*

(6) TEMPERATURE TESTS—Temperature tests on induction motors are made in much the same manner as those on direct-current motors. The motor is run in the ordinary way belted to a direct-current generator, which in turn is loaded on resistances. In the case of small machines, this test is made on tables similar to those used for the commercial testing of direct-current motors. The length of run depends of course on the size of the machine, but with sizes up to 100 hp., the run is usually three hours with readings at intervals of volts, amperes, and motor and generator speed. At the end of the run the temperatures of primary iron and copper, secondary copper and the surrounding air are taken by thermometer. The primary resistance in the case of a squirrel cage motor and the primary and secondary resistances in the case of a motor with a wound secondary are also taken at the end of the run in order to find the rise in temperature by resistance.

The customary rise allowed in induction motors, for a complete temperature test on full-load, is about 50 degrees Centigrade, but this value is seldom reached, since the efficiency of a motor becomes too low if it is rated for an ultimate temperature rise of 50 degrees Centigrade, when run at full-load.

COMMERCIAL TESTING OF INDUCTION MOTORS

The commercial testing of induction motors consists in a temperature test and an insulation test, followed by a no-load reading, or a point on the running saturation curve. In the case of large motors these tests are made in the same way as those described under experimental testing, but in the case of small motors which have to be tested in great number special arrangements have to be made for testing a number of machines simultaneously.

Small Motors—The equipment for testing induction motors consists of tables like those used for testing small direct-current

*See "Applications of Alternating-Current Diagrams. The Heyland Diagram." *The Electric Club Journal*, Vol. I., p 658, and Vol. II., p 118; also "A Practical Vector Diagram for Induction Motors," by H. C. Specht. *The Electrical World and Engineer*, Vol. XLV., p 388.

machines. The motors are placed on one end of the table, at the other end of which are direct-current generators which may be belted to the motors. The belt tension is adjusted by moving the cast iron table plates on which the motors rest, by means of a screw and hand wheel. Cables are permanently connected between the distributing board and each of the tables, their ends being so arranged that they may be connected to the terminals of the induction motors. There are also cables permanently connecting the direct-current generators with resistance racks. The field rheostats of these generators are located at the foot of the distributing board. Fig. 88.

On the distributing board there are two sets of four terminals connected to the instrument table. One set is to be connected to

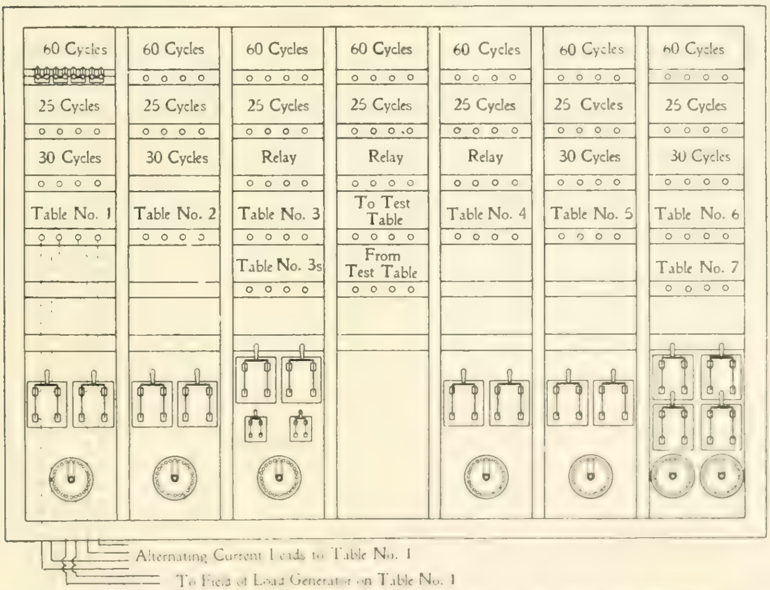


FIG. 88—DISTRIBUTING BOARD FOR TESTING SMALL INDUCTION MOTORS

the power whether direct from the line or through transformers. The other set is to be connected to the terminals of the motor table on which the motor to be tested is placed. It will thus be seen that it is possible to measure the input to the motor under test, by means of instruments on the table. The relays shown are used for bringing power from the transformer board which is in the rear of the distributing board and is practically the same as that shown in Fig. 76.* The instruments used in commercial testing are, a

*See *The Electric Club Journal*, Vol. II., p. 320.

voltmeter and a dynamometer; wattmeter readings being seldom taken.

All of the tables are usually kept running at once, the motors being started up and shut down in succession. Connections between different parts of the board are made by means of lengths of cable and plugs as previously explained. In the case of three-phase motors all three leads to the motor are connected to the power through the table, connections being made as shown in Fig. 89. In the case of two-phase motors only two leads of the motor are connected through the table, the other two going direct to the power, as shown in Fig. 90. It is necessary to make all four connections between the test table and the power in order that the voltage may be read.

Preparation for Test—The motors are belted to the generators

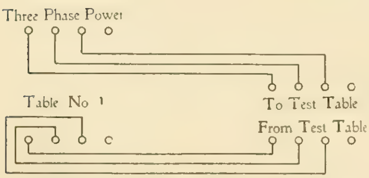


FIG. 89—PLUG CONNECTIONS FOR RUNNING A THREE-PHASE INDUCTION MOTOR

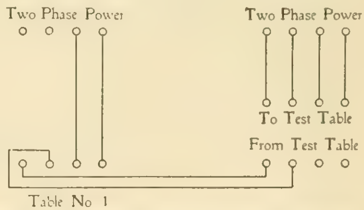


FIG. 90—PLUG CONNECTIONS FOR RUNNING A TWO-PHASE INDUCTION MOTOR

on their tables, connections made as described above, the voltage brought down if necessary and the motor started by closing the switches corresponding to the motor table in question. It is well first to insert all the rheostat resistance in the field of the load generator and to plug up the resistance racks for small load.

In loading the motor, an overload of about 25 per cent. should be given at first, as the iron wire spirals on the racks heat very rapidly, decreasing the current. When the motor has been loaded, it is simply necessary to remove the plugs from the test table, one by one and plug up directly to the power. The motor will run single-phase during these short intervals with no damage. The plugs to the test table may now be inserted in the proper places to run the next motor, and this motor started in exactly the same way.

As soon as a motor has been started up the bearings must be examined to see that the oil rings run properly; the belt should then

be tightened and the load applied. During the test the bearings must be examined from time to time to see that they are running cool.

Readings are taken at the beginning and at the end of the test, of the terminal volts, amperes, motor speed and generator speed. When a machine has been run for one hour it is stopped, the temperature of its primary windings taken and its pulley removed. When all the machines have been run in this manner a no-load reading is taken on each machine and then the insulation test is made in exactly the same way as with other machines.

The insulation test in the case of a three-phase motor is simply made from the primary winding to the iron. In the case of a two-phase machine it is made from each phase to the iron and also between the phases.

In checking the results of commercial tests with standard curves, the full-load slip is checked with the full-load slip in the curve, and the no-load amperes with the amperes at full voltage on the running saturation curve. In the case of large motors wattmeter readings are taken and these checked with corresponding readings on the standard curves.

EDITORIAL COMMENT

Utilizing Known Principles

About eleven years ago in connection with tests which were being made on high tension insulators in the laboratory of the Electric Company, the luminous discharge from high tension wires was noted and investigated. Fine wires which were connected to the high tension terminals were found to become luminous, to give forth a humming sound and to produce ozone. The loss of energy in these various forms was further corroborated by wattmeter measurements. At the suggestion of Messrs. Nunn, the high tension investigation was continued on an experimental line in connection with the Telluride plant in Colorado. Final tests and measurements were made by Mr. Mershon which showed that under the conditions under which he worked there was a rapid increase in the loss between wires when the voltage reached approximately 60 000 volts and that at any considerable increase above this voltage the loss became very considerable.

This phenomenon was the starting point of an investigation by Professor Ryan. He saw that a definite scientific knowledge respecting the limiting voltage in transmission was of very great engineering importance. The difficulties of accurate and definite measurements at very high voltages are probably not appreciated except by those who have personally encountered them in experimental work. Methods and apparatus which are ordinarily useful become of little value. Professor Ryan has told me that this problem weighed on his mind for a long time. The more he studied it the more interested he became. He conceived that a new instrument of measurement was necessary and took up the kathode ray oscillograph and developed it for the primary purpose of utilizing it in the investigation of the high voltage discharge. The investigation was complete, facts and formula were developed showing the voltages at which discharge begins to take place with wires of different sizes. Theory, formula, the results of Mr. Mershon and the laboratory tests of Professor Ryan were found to agree with remarkable accuracy. The paper of Professor Ryan* describing this work cleared up and put in definite engineering form the physical facts regarding a phenomenon which was involved in

*"Conductivity of the Atmosphere at High Voltage," American Institute of Electrical Engineers, February 26, 1904.

mystery and which promised to be a serious limitation in high voltage transmission.

The description of the kathode ray oscillograph by the young man, who, during the past year, was associated with Professor Ryan as instructor and is now an apprentice in the works of the Electric Company, is of interest as a scientific paper. It is also of interest from other points of view. One of the most striking features of Professor Ryan's work, both on the oscillograph and in the investigation of the phenomena relating to electric discharge between wires is the simplicity of the means and methods which he uses. He takes elements which are elementary and well known and applies them most ingeniously to accomplish his purpose. The method of increasing or decreasing the amount of gas in the tube is most simple and elegant. Everybody who is familiar with alternating current knows that the current through a choke coil becomes less as the frequency is increased and the current to a condenser becomes greater. These simple principles are used in a combination of inductance coils and condensers in such a way that they act like a sieve in separating the fundamental from its harmonics in an irregular wave form. When one grasps the significance of the simple arrangement which he uses he has a new appreciation of the action of condensers and coils in an alternating-current circuit.

It is rarely that the story of the simple steps taken by a scientific investigator are more interestingly told than in the accounts of this elegant piece of work by Professor Ryan. Those who aspire to scientific research will do well to study the methods which he employs. CHAS. F. SCOTT.

Single-phase Comment

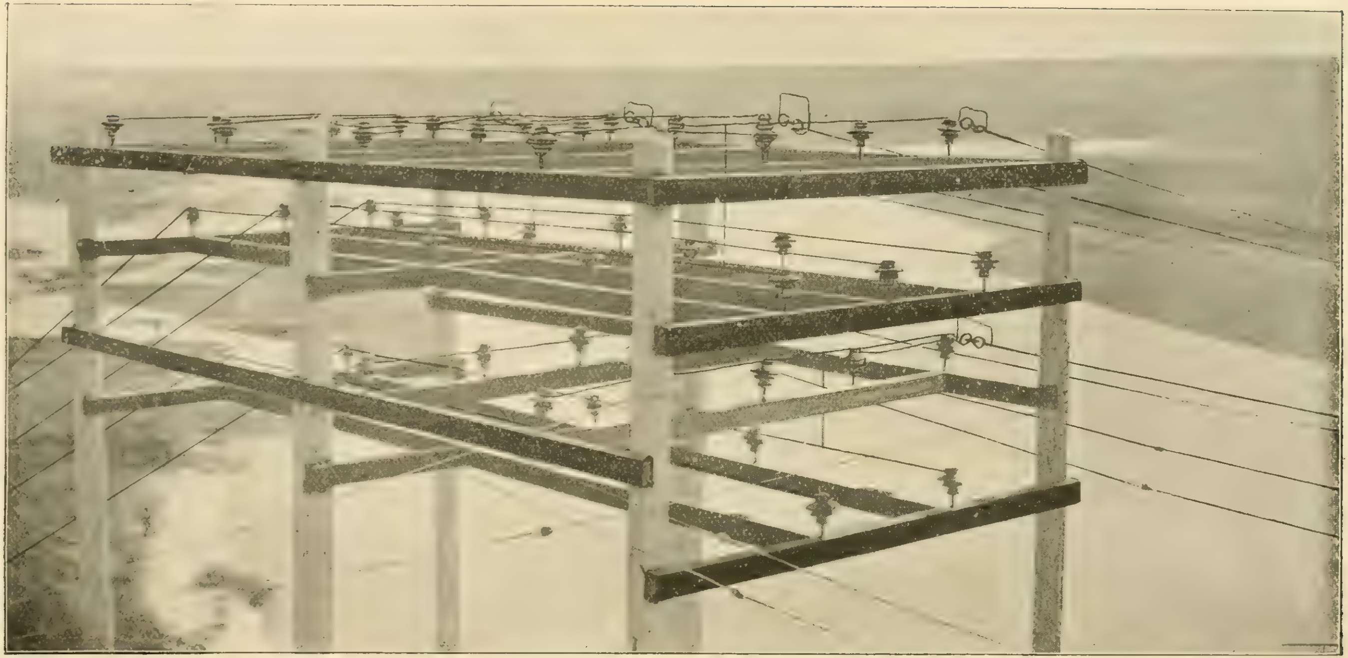
The article "The Single-Phase Railway System, Its Field and Its Development," in the July JOURNAL, by Mr. C. F. Scott, has been the basis for editorial comment and several communications in the Electrical World & Engineer. In the issue of August 19th, Mr. C. L. de Muralt takes exception to the conclusions given in the original article and says that he believes there are other engineers, both here and in Europe, who hold that the single-phase railway system is not at all essential for heavy and

long distance railway service, that no single-phase motor and single-phase system as yet fulfill the ideal requirements and that other forms of motors are better adapted to meet the demands of heavy traction than the series compensated single-phase motor. The reasons for this position are stated to be principally the greater efficiency and lower cost combined with certain technical features. For particulars reference is made to discussions at the annual meetings of the American Institute of Electrical Engineers in 1902 and 1905.

A recent number of the Railway Age publishes the following:

"At the recent general meeting of the Association of German Engineers, held at Magdeburg, Dr. Eichberg, of Berlin, presented a paper dealing with the recent progress and future of electric train haulage. In the course of his observations, the author stated that the Prussian railway ministry had come to the conclusion that, from an electrotechnical point of view, neither the double overhead conductor nor the third rail was suitable for the working of trains on large railway networks. A technically satisfactory solution, as had been clearly proved by the experiments at Spindlersfeld, near Berlin, was afforded only by the combination of a single aerial wire with high pressure current and a single phase motor. The same system had been employed with success in the Stubbai Valley, Innsbruck. It practically presented no material difficulties. A pressure of 5 000 volts to 6 000 volts has been used on the Spindlersfeld line, and it would be possible to employ a pressure as high as 15 000 volts on mountain railways. On the German line in question, electric heating had been adopted, the current being mostly used for this purpose while the trains were at rest, and also occasionally during running at full speed. The heating was regulated by a switch on the driver's platform. As a result of those experiments, the Prussian railway ministry had decided to introduce the single-phase system on the section connecting Hamburg, Blankenese and Ohlsdorf, which was to be set in operation in a year."

From the foregoing it is seen that there is a very active interest in the application of alternating current and that the claims of the single-phase have been challenged by the advocates of polyphase apparatus and further that the adoption and success of the single-phase system can come only as its superiority over other methods can be conclusively shown.



NORTH TOWER, SNAKE RIVER SPAN, LEWISTON-CLARKSTON COMPANY

Distance between towers, 1925 feet; size of transmission wire, No. 4 B. and S. hard drawn copper; approximate tension per wire, 900 lbs. This span has been up for eight months and in service with current on for four months. The flexible connections allow the wires to swing freely during the prevailing heavy windstorms. The wind velocity has been occasionally as high as 50 to 65 miles per hour. Since installation temperature variations from 10 below zero to 110 degrees above zero have been recorded and no trouble has been experienced.

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TESTS ON INTERURBAN SINGLE-PHASE EQUIPMENTS

GRAHAM BRIGHT

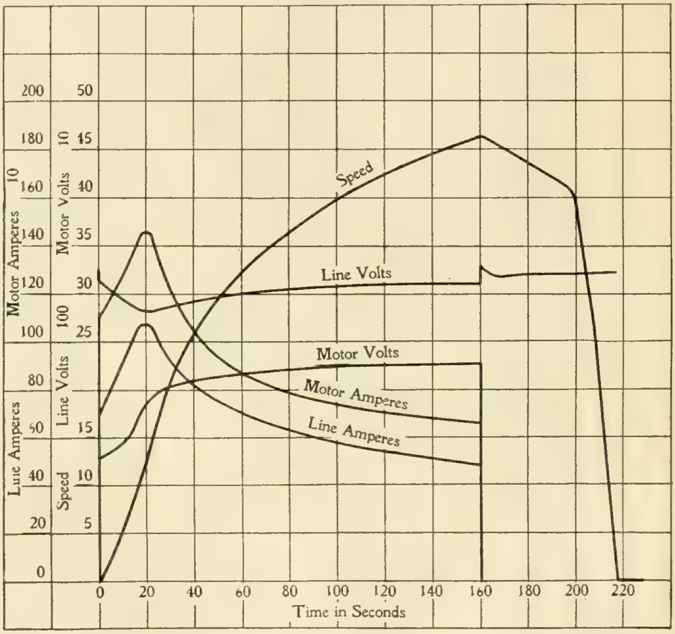
THE advent of the successful single-phase alternating current railway has made it necessary to conduct a large number of tests to determine accurately the various characteristics of the system in actual service. Tests of this nature are considerably more difficult to make on an alternating than on a direct current system on account of the larger number of factors that enter into an alternating current system, and also on account of the greater sensitiveness of alternating current instruments to changing currents, especially on a moving car.

The usual method of making a test on a moving car is to lay out a given length of run on a level straight track and then to make a run with the car, just as near as possible like it would be made in actual service. The rate of controller notching is decided upon before the test and also the point at which the current is to be cut off, from which point the car is allowed to drift until the brakes are applied. Instrument readings are taken at predetermined intervals. These readings are afterward corrected, tabulated and plotted in the form of curves. These curves show very plainly just what takes place from the time the car starts until it reaches the end of the run, and are somewhat analogous to a steam engine indicator card but of course cover more ground.

When testing a direct current car, readings may be taken at intervals as close as every two seconds, but when testing an alternating current car, it is not advisable to try to take readings at closer intervals than every five seconds, owing to the more sensitive characteristics of alternating current instruments.

The actual readings necessary in testing an alternating current equipment are those which give the trolley volts, trolley amperes, trolley kw, motor volts, motor amperes, motor kw

and speed. From these readings the apparent trolley kw, apparent motor kw, trolley power factor and motor power factor can be calculated. A timekeeper is also necessary who carries a stop watch and rings a bell or blows a whistle at intervals to notify the observers just when to take their readings. If possible there should be a second timekeeper to call out the number of each signal so that each observer will get his readings down in the proper place.



Gear ratio, 18:64.
Size of wheels, 37 in.
Length of run, 2 miles.
Time of run including stop, 227.5 sec.
Length of stop, 10 sec.
Schedule speed, 31.65 miles per hour.
Average speed, 33.1 miles per hour.

FIG. I. SPEED, VOLT AND AMPERE CURVES FOR TEST NO. 10 OF 49.4 TON CAR EQUIPPED WITH FOUR 75 HP WESTINGHOUSE SINGLE-PHASE ALTERNATING CURRENT RAILWAY MOTORS.

When long tests are made over a complete section of any system, an additional observer is needed to mark locations, position of controller handle, and the lengths of stops.

In selecting observers for a car test men should be chosen who are familiar with test work and instrument reading so that they can read an instrument accurately at a glance. Several preliminary tests should be made when the observers are first brought together

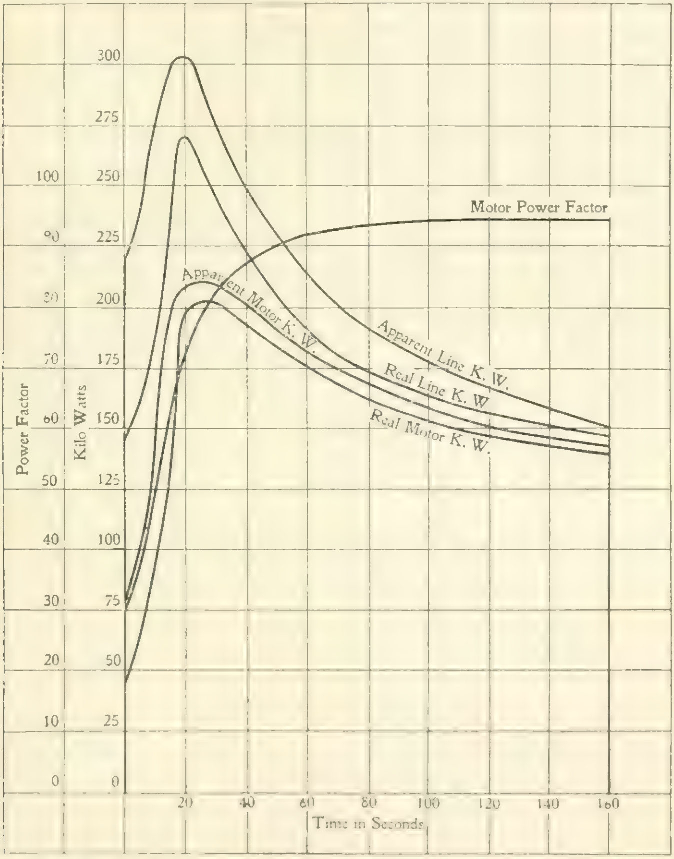
Correction in Captions—Fig. 2, page 653, and Fig. 4, page 655,

The caption "REAL LINE K.W." should read *Apparent Motor K.W.*

The caption "APPARENT MOTOR K.W." should read *Real Line K.W.*

so as to make each man familiar with his surroundings and the instrument he is to read.

For the measurements of current and power, from which the accompanying curves were plotted, Westinghouse alternating current portable instruments were used. Dead beat alternating-current voltmeters were used to measure voltage. Speeds were ob-



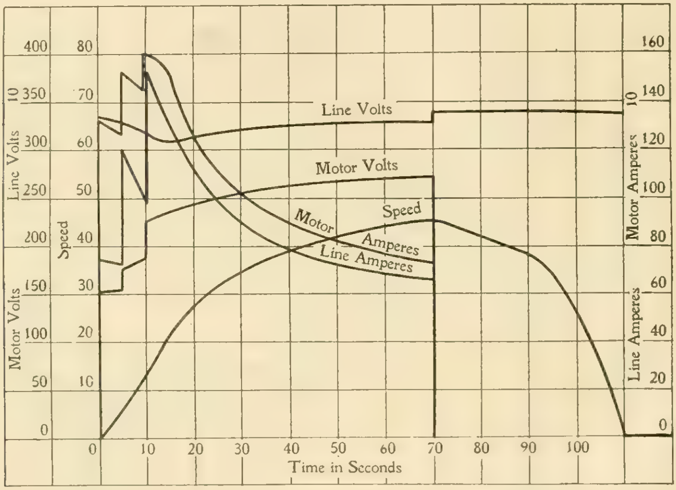
Kw-hrs. per car mile, 3.7. Watt-hrs. per ton, mile, 75.
Average power factor, 81.6.

FIG. 2. KILOWATT AND POWER-FACTOR CURVES FOR TEST NO. 10 OF 49.4 TON CAR EQUIPPED WITH FOUR 75 HP WESTINGHOUSE SINGLE-PHASE ALTERNATING CURRENT RAILWAY MOTORS.

tained by means of a direct current magneto generator, driven by one of the car wheels. From this magneto generator, leads

were run up into the car, and the observations made on a direct current voltmeter. All instruments were carefully calibrated before or after any important tests.

Two tests taken recently are shown in Figs. 1, 2, 3 and 4. Curves 1 and 2 show a test, No. 10, on a 49.4 ton interurban car equipped with four 75 hp Westinghouse single-phase alternating current railway motors geared for a speed of about 50 miles per



Gear ratio, 18:57.
Size of wheels, 33 in.
Length of run, 1 mile.
Time of run including stop, 120 sec.
Length of stop, 10 sec.
Schedule speed, 30 miles per hour.
Average speed, 32.7 miles per hour.

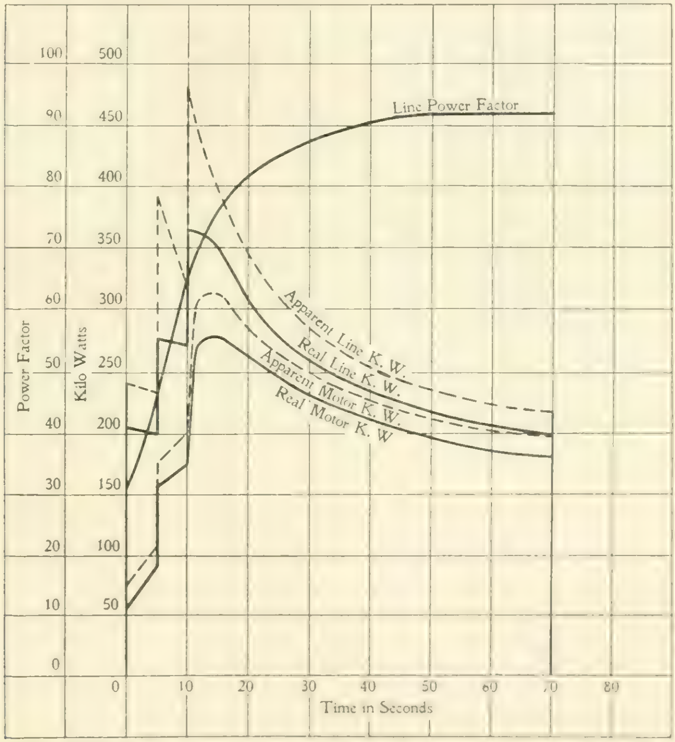
FIG. 3. SPEED, VOLT AND AMPERE CURVES FOR TEST NO. 9 OF 37.5 TON CAR EQUIPPED WITH FOUR 75 HP WESTINGHOUSE SINGLE-PHASE ALTERNATING CURRENT RAILWAY MOTORS.

hour. This test extended over a run two miles in length. The controller was operated to the full-on position in about 15 seconds and was thrown off about 3 000 feet from the end of the run. The car was allowed to drift about 2 500 feet, and then the brakes were applied. In looking at the speed curve, the acceleration for the first 30 seconds is seen to be 0.7 mile per hour per second. In another test on this car the initial acceleration was increased to one mile per hour per second by operating the controller a little faster. In this test the maximum apparent line kw was about 350. An acceleration of one mile per hour per second is higher than is ordinarily required with cars of this weight and gearing. The decrease in speed during coasting and braking is shown very clear-

ly in the curve. The rate of acceleration can be obtained at any point by taking a tangent to the speed curve at that point.

The difference between the line real kw and motor real kw curves represents the losses in the transformer and car wiring.

The kw per car mile and watt-hours per ton mile can be calculated from the average kw which is obtained by integrating the



Kw-hrs. per car mile, 4.23. Watt-hrs. per ton mile, 112.8.
Average power factor, 81.

FIG. 4. KILOWATT AND POWER-FACTOR CURVES FOR TEST NO. 9 OF 37.5 TON CAR EQUIPPED WITH FOUR 75 HP WESTINGHOUSE SINGLE-PHASE ALTERNATING CURRENT RAILWAY MOTORS.

line real kw curve and dividing by the entire time of the run including the stop.

The actual power drawn from the line is very low as the car starts but rises rapidly, reaching a maximum a little later than the maximum for the apparent kw.

The power factor is rather low at the start but rises very rapidly, passing a value of 80 per cent. in less than twenty seconds, and soon reaching 91 per cent. in one test and 94 per cent. in the other. The average power factor will run from 80 to 85 per cent. in these tests and with longer runs at full speed would be considerably higher.

The average power factor may be obtained by dividing the average real kw by the average apparent kw.

The actual heating of the motors and transformers depends upon the value of the mean square current. The square root of the mean square current can be readily obtained by plotting the squared values of the current readings. This curve is then integrated and divided by the total time of the run, including the stop. The square root of this value will be the square root of the mean square current. This result is the value of the constant current which would produce the same heating as the actual varying current. This value will determine whether the motors and transformers are working above or below their capacities.

The sudden rise in the line voltage curve at 160 seconds (Fig. 1) is due to the line current being cut off, which allows the voltage to rise owing to the decrease in line drop. The lowering of the load on the engine and generator will also cause the voltage to rise a little.

The gradual rise of the motor volts after the controller is on full, is due to the decrease in the line and transformer drop.

Figs. 3 and 4 show a test, No. 9, on a somewhat lighter car with the same equipment and geared for about the same maximum speed. The length of run in this case was only one mile, which is a shorter run than the equipment is intended for. Readings were taken for each of the three notches in the controller. A much higher acceleration was used in this test, which accounts for maximum values of the kw curves being somewhat higher than in the previous test.

Notwithstanding the fact that a considerable drift was allowed, a schedule speed of 30 miles per hour was obtained. This is a very high schedule speed for such a short run and accounts for the watt hours per ton mile being higher than it is for the other test.

Curves were calculated and laid out for operation by direct current motors using the same weight of car, the same length of run, same schedule and same maximum speeds. The watt hours

per ton mile found were approximately the same as were obtained in the tests just described.

A further test of importance on an alternating current equipment is a service test. For this test a typical run is laid out from which the square root of the mean square current can be calculated. This run is repeated over and over again for about eight hours to determine the suitability of the apparatus for regular service. At intervals, temperature readings are taken on the transformer windings and motor fields. At the end of the run, temperatures are also taken of the armatures and commutators. This test determines the actual capacity of the motors and transformer for any given set of conditions.

There has been considerable skepticism among engineers as to whether a car could be accelerated rapidly enough when equipped with and operated on the single-phase alternating current system. A number of acceleration tests have been made on different cars, the controller being operated at various rates of speed, and no difficulty has been experienced in obtaining initial accelerations as high as two miles per hour per second.

It is also possible with the alternating current system to throw the controller on full at once without injury to the motors.

GAS ENGINES IN ELECTRIC RAILWAY SERVICE*

J. R. BIBBINS

THE load on an electric railway, and particularly on a suburban electric railway, is of quite a different character from the usual electric lighting load, in that its fluctuations are sudden and extreme. In Fig. 2 are shown six typical load curves from different cities as designated. No. 1 represents the load from the Pittsburg surface railway, No. 2 from the Detroit surface railway, No. 3 from the Manhattan elevated system, New York, No. 4 an interurban system near Cleveland. No. 5 represents the lighting load of the New York Edison Company and No. 6 a Pittsburg central lighting station. Apparently the only

FIG. I—WESTINGHOUSE DOUBLE-ACTING GAS ENGINE FOR GENERATOR DRIVING

difference between railway and lighting loads is that the morning railway peak is more distinct than in the lighting system. On the interurban system the average day load is high with considerable fluctuations. The load curve, however, does not tell the story as well as an ordinary recording meter chart, Fig. 3, which corresponds to load curve No. 4, Fig. 2. This chart shows the violence and suddenness of the fluctuations which are impressed upon a railway prime mover. In this particular case, and day, steam turbines were used and only one turbine was in service, whose full load capacity was about 1 500 amperes. But in any

*The topics discussed in this article are the salient features of a paper by the same author read before the American Street Railway Association, Sept. 28, 1905.

case the load demand would be the same, irrespective of the type of prime mover used. The charts give a striking perspective view of the severe service which must be met by the gas engine in its comparatively new application. Its ability to perform such service has long been proven by the successful use of gas engines for driving large manufacturing works, where the load is fully as fluctuating and varying in its demand upon the prime mover as any street railway load. Furthermore, most large factories are electrically driven by the alternating-current system, and it is particularly noteworthy that gas-engine driven units are successfully operating in parallel at a number of plants,

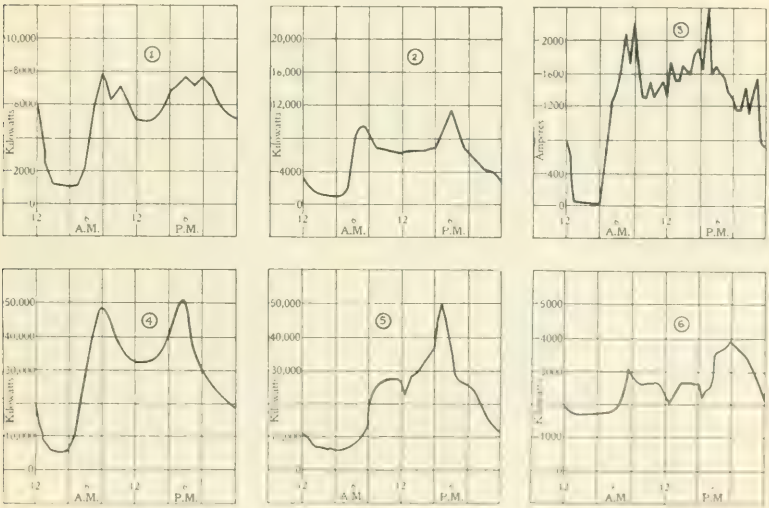


FIG. 2—TYPICAL POWER STATION LOAD CURVES

notably in several of the large manufacturing plants in the Pittsburg district.

PRODUCER GAS

At the present time it appears as if the entire future development of the gas engine is linked with that of the gas producer, especially with that producer capable of operating efficiently on low grade bituminous coal. Some recent government tests summarized in Figs. 4 and 5 show striking results along this line. These tests were conducted with many grades of coal from the richest West Virginia bituminous down to the poorest western lignites. A 235 hp Westinghouse gas engine, belted to a 175 kw

generator, absorbed the gas generated from an R. D. Wood Company's Taylor producer. The duty of this small plant for various grades of coal is shown in Fig. 4. The coals are here uncorrected for moisture, which accounts for the rapid rise in fuel consumption with the low grade lignites which contain much moisture.

Comparative tests with a belted steam plant of similar capacity were also conducted by the government with the results

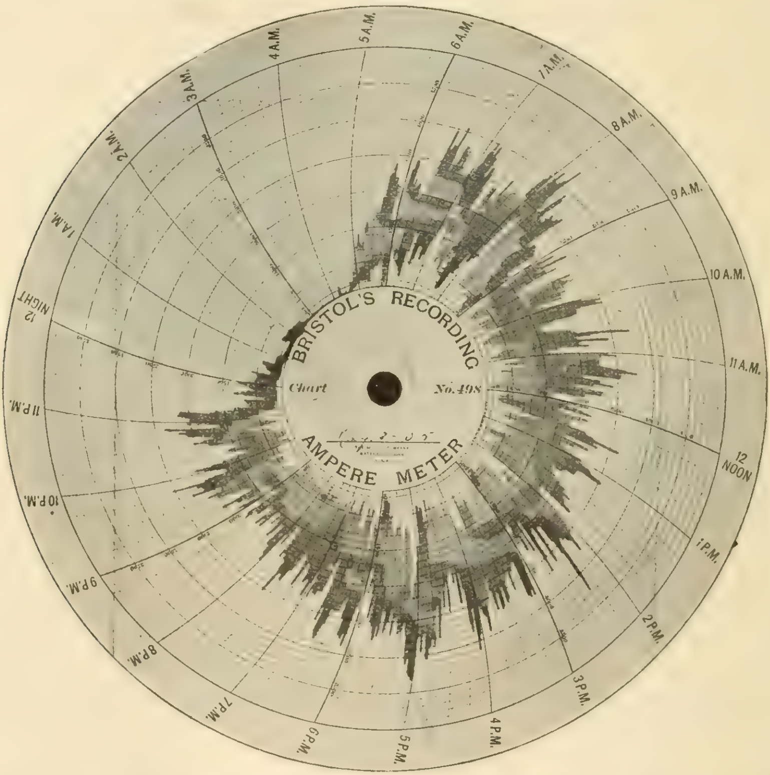


FIG. 3—RECORDING METER CHART, SHOWING FLUCTUATIONS OF INTERURBAN LOAD

shown in Fig. 5, all based on dry fuel and with the steam engine running non-condensing. At the calorific value of average steam coal, 13 000 B. t. u. per pound, the gas plant consumed less than two pounds per kilowatt-hour and the steam plant five and one-half pounds per kilowatt-hour. Running condensing the duty of the steam plant would probably be from four to four and one-half pounds per kilowatt-hour. These results show in a striking man-

ner what may be accomplished with even a small gas plant. It may be fairly said that the fuel economy of a properly equipped gas plant is fully twice that of a condensing steam plant of corresponding character.

THE WALTHAMSTOW STATION

One of the finest gas power central stations now in service is illustrated in Fig. 7. It contains thirteen direct connected Westinghouse engines and eight Dowson anthracite producers,

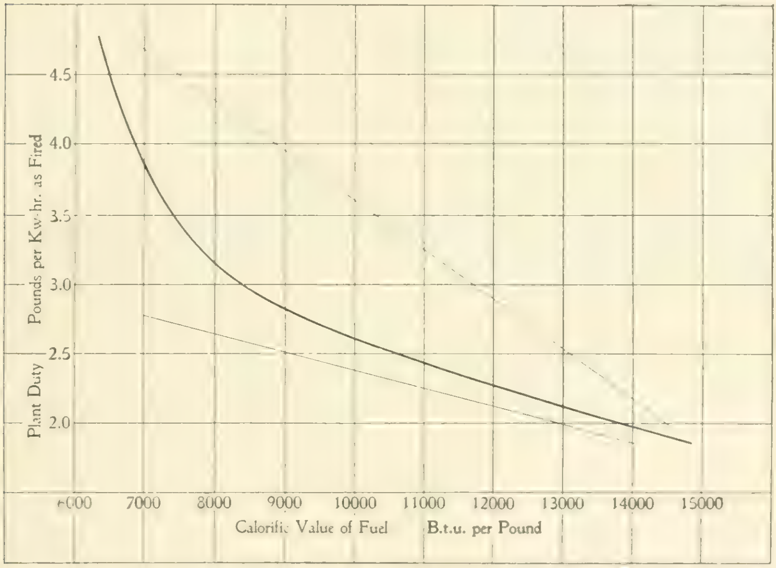


FIG. 4—CURVE—GAS POWER PLANT DUTY WITH PRODUCER GAS, SHOWING THE RAPID DECREASE IN COAL CONSUMPTION WITH HIGHER GRADE COALS. FULL LOAD AVERAGES 17 TESTS. BITUMINOUS COALS AND LIGNITES. COAL AS FIRED—UNCORRECTED FOR MOISTURE

totaling 2000 kw capacity. It supplies light and power to the London borough district of Walthamstow and power for the borough tramways. Data from this plant covering 12 days continuous operation show that with an average load factor of 35 per cent the plant consumed less than one and eight-tenths pounds of coal per kilowatt-hour, including fuel for all purposes. Throughout the year the coal consumption averages about two pounds per kilowatt hour.

Table I. shows the results of two years operation of this plant.

TABLE I.

OPERATING COSTS—GAS POWER STATION

Walthamstow district council. From "Garcke's Manual."

SUPPLY RECORD (Year ending March 31st)	1904	1903
Kw hrs. generated	1,019,326	659,796
Kw hrs. sold	814,187	542,423
Gross efficiency of system, per cent	80	82.25
Load factor	15.45	15.25
OPERATING COSTS	Cents per kw-hr. generated	
Coal* and other fuel, delivered	0.745	0.89
Oil, waste, water ** and general supplies	0.306	0.37
Wages of workmen	0.590	0.67
Repairs and maintenances†, total	0.065	0.19
Total operating cost	1.706	1.925

*Cost of coal averaged $6.50 per ton in 1902-3; $6.75 in 1903-4.

**Artesian well not yet in service; water purchased.

†Including buildings, mechanical and electrical equipments, storage batteries and distribution system.

TABLE II.

OPERATING COSTS.*

London metropolitan boroughs, year ending March 31st, 1904.

	Plant capacity, kw	Output sold	Ratio sold generated per cent	Load factor, per cent	Operating costs—d per kw-hr. sold: Fuel	Supplies**	Labor	Repairs***	Operating costs
Average of 11 steam plants†	2.799	2,997,500	83.9	17.25	.597	.059	.214	.218	1.088
Walthamstow.	810	1,019,326	80.0	15.45	.368	.152	.288	.048	0.856
Savings per cent (favor gas)					+38.4	††	—13.5	+78	+21.5

*Data from "Electrical Times" financial reports.

**Oil, waste, water and miscellaneous supplies.

***Includes repairs to buildings, electrical equipment and distribution system.

†Steam plants—Hackney, Stepney, Poplar, Battersea, Hammersmith St. Pancras, Fulham, Shoreditch, Southwark, Hampstead, Islington.

††Artesian well not in service; water paid for.

The operating costs appear high on account of the excessive cost of coal in these London districts. Table II. compares these costs with operating costs from 11 borough steam plants similarly situated and all with greater capacity and higher load factor.

It will be noted that Walthamstow shows a saving of 38 per cent in fuel and 22 per cent in operating costs. Its working costs averaged about 40 per cent of the revenue from current.

UP-KEEP OF GAS ENGINES

A 500 kw belted gas engine plant at Bradford, Pa., gives a striking illustration of the efficiency of gas engines when the equipment is properly operated and taken care of. The plant is in its seventh year of service; yet the repairs and cost of maintenance during the last two years have only been $92.70 per year, or 11.6 cents per hp year. Table III. shows the complete operating costs of this plant for the last two years, averaging eight and one-half mills per kilowatt-hour on a load factor of less than 20 per cent, and this with antiquated electrical apparatus.

Table III.

OPERATING COSTS

500 hp gas power station, Bradford, Pa.

	1904	1903
Annual output, kw-hr	804.092	780.300*
Station load factor, per cent	10.54	....
Gas consumption, cu. ft	20,056.00	18,162.00
Plant duty (including heating) cu. ft., per kw-hr	24.9	22.4
Average price of gas, cents per 1 000 cu. ft.	12.32	10.5
Operating Costs	Cents per kw-hr. generated	
Fuel (including heating)	0.307	0.384
Labor, power station only	0.380	0.392
Supplies	0.059	0.072
Repairs, engine and electrical equipment	0.079	0.050
Repairs, gas engines only	0.010	0.013
Total works or operating costs	0.825	0.898

*Estimated from nine months' metered output.

COMPARATIVE COST OF GAS VS. STEAM POWER

Fuel saving is by no means the only item to be taken into account in determining whether one system of power generation is cheaper in the end than the other. This is a typical engineering problem involving not only technical but also economic considerations of which the most important is that of comparative capital cost. As the solution of the problem often results differently than anticipated, the following diagram, Fig. 6, was prepared from careful estimates to indicate within what ranges of fuel cost gas power will be cheaper than steam power.

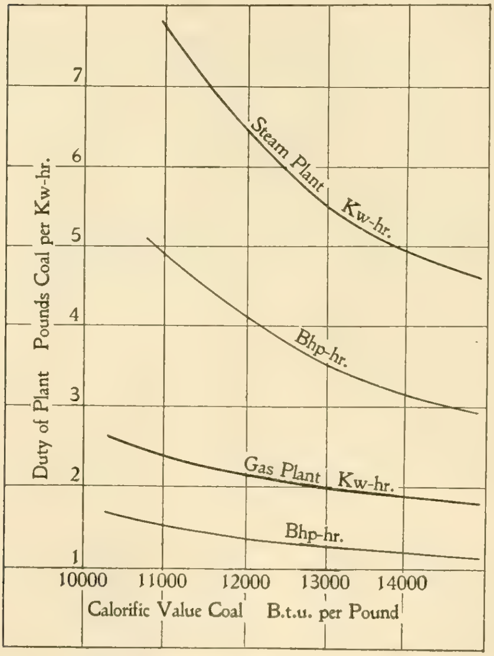


FIG. 5—CURVE—COMPARATIVE ECONOMY TESTS OF STEAM AND GAS PLANTS UNDER SIMILAR CONDITIONS WITH LIKE FUEL. FULL LOAD AVERAGE OF 14 TESTS EACH

GAS TESTS........23 TO 43 HOURS
STEAM TESTS...... 10 "
DRY COAL

Two 5 000 kw railway plants were assumed operating upon a load factor of 60 per cent. with high grade equipments throughout and economies in both instances representing the best modern practice. The capital cost of the gas plant equipment totaled 30 per cent. in excess of the total of the steam plant. The lower pair of diagonals represents the cost of fuel only. In this item the gas plant has a great advantage. To this is added the cost of labor, supplies and repairs, giving the total operating costs represented by the second pair of diagonals. By still further adding fixed charges (represented by interest, depreciation, insurance, etc.), the upper pair of diagonals is obtained. The heavy gas line represents a fair average cost at the present time. It will be observed that the two lines of total costs intersect at a point represent-

ing coal at slightly less than $1.00 per ton. This means that this plant operating under the assumed conditions would not pay with gas power if coal is cheaper than $1.00 a ton. On the other hand, with higher priced coals the saving would be considerable. Thus with $3.00 coal about 25 per cent of the excess cost of the gas plant over the steam plant would be realized; or, in other words, the gas plant would soon make up for its excess cost.

In this manner any power proposition, however circumscribed by special conditions, may be brought to a commercial basis of profit versus loss. It is poor engineering to advocate anything

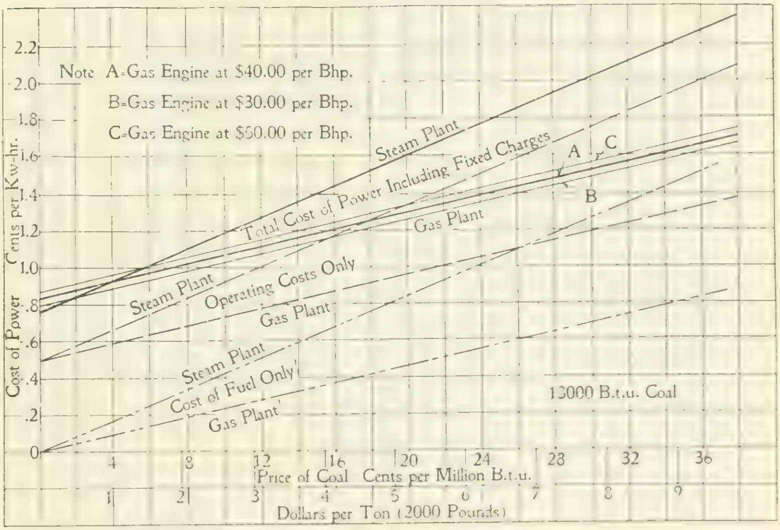


FIG. 6—CURVE—COMPARATIVE COST OF GAS AND STEAM POWER IN A 5 000 KW PLANT, 60 PER CENT LOAD FACTOR, FOR DIFFERENT GRADES OF COAL. FOR ASSUMED CONDITIONS. STREET RAILWAY LOAD

indiscriminately. Every system, however meritorious, has its limitations. Until the excess cost of gas power plants is somewhat reduced, they will be under a slight handicap, but the greatly increased economy of gas working and the excellent results obtained in the field, point to a wide application of gas power as a means of reducing power cost.

In the light of past performance, rather than in the light of prophecies regarding the future, the subject may be well summarized by the following conclusions:

First—That the gas engine has been brought to a state of de-

velopment where it is capable of doing the same work as the steam engine, with far greater efficiency and usually at reduced cost.

Second—That the producer has been so far perfected as to be a reliable and more efficient generator than the steam boiler.

Third—That the gas power plant "in toto" is entirely suitable for even the severe service incident to electric railway operation.

Fourth—That its component parts, engine and producer, are possessed of characteristics leading to harmonious coöperation.

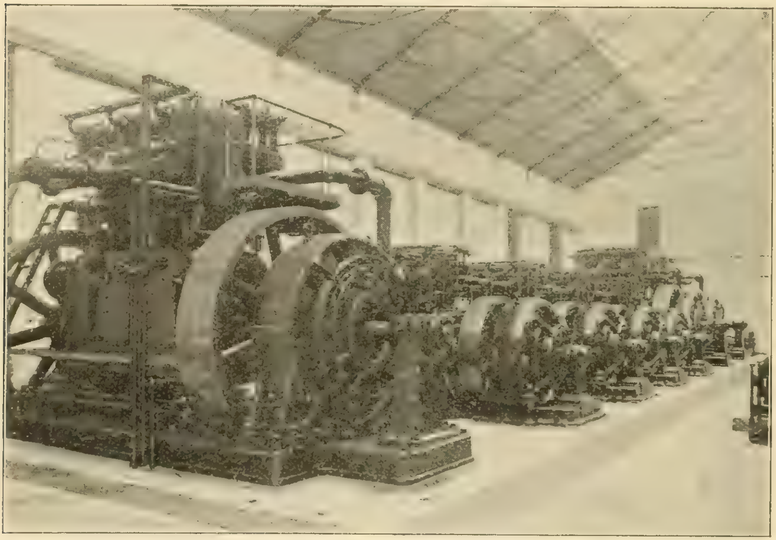


FIG. 7—800 HP GAS POWER RAILWAY AND LIGHTING STATION, BOROUGH OF WALTHAMSTOW, LONDON

Fifth—That practical difficulties incident to gas power working have been so far overcome as to warrant commercial confidence.

Sixth—That experience with gas power in almost every known line in modern industry has proven its general sufficiency for any power service.

An important gas engine plant is just now being put into operation at Warren, Pa., for operating the new Warren & Jamestown single phase interurban railway system. Similar equipments are building for the Union Traction Company of Independ-

ence, Kan., both driving engine type alternators in parallel. One of the units will be of 1 000 b. h. p. capacity, the others of 500 b. h. p. of the type shown in the accompanying illustration, Fig. 1.

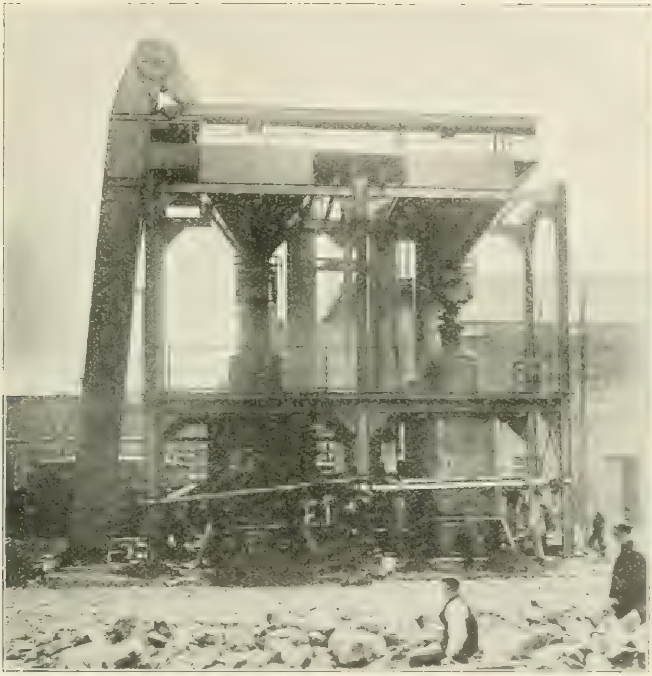


FIG. 8—TYPICAL MOND PRODUCER PLANT AT HEYSHAM HARBOR, SHOWING COAL-HANDLING APPARATUS

The heavy duty type double acting gas engine seems destined by necessity to find universal adoption in all cases where large powers are required.

ALTERNATING-CURRENT ELECTROLYSIS?

S. M. KINTNER

THE recent completion of a test of alternating-current electrolysis extending over a period of one year, has given some interesting data on this important subject.

A number of experimenters have reported from time to time the results of laboratory tests. These have not been in very consistent agreement as to the actual existence of electrolytic action. The writer undertook to check some of these observations, but with very

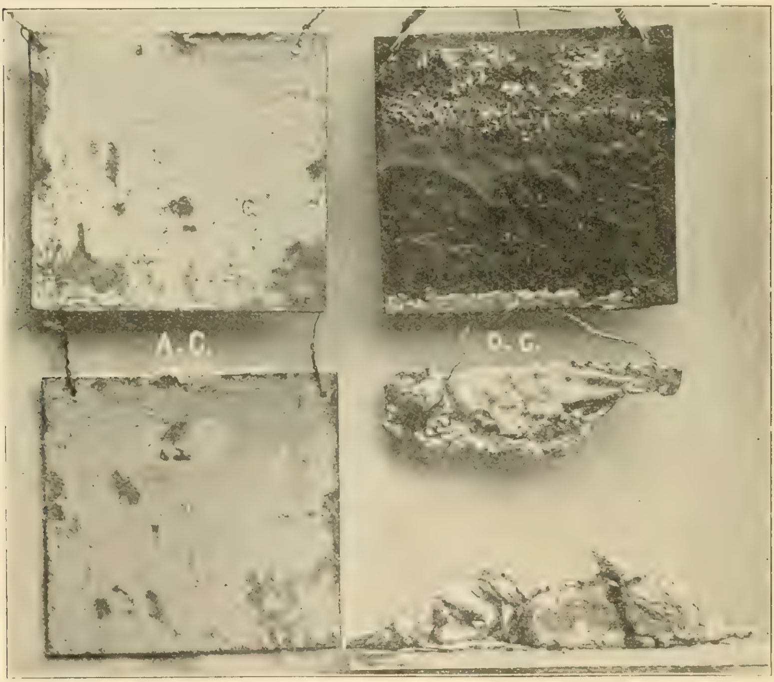


FIG. I—THE LEAD PLATES JUST AS THEY APPEARED AFTER BEING RAISED FROM THE JARS

poor success. The general conclusions reached from the laboratory tests were:

(a) That for iron and steel there was no appreciable action judging both from a careful visual inspection of the metal electrodes and from their changes in weight.

(b) That for lead and tin-lead alloys there was an exceed-

ingly slight action which was estimated at approximately one-half of one per cent. of that which would have resulted from direct-current action.

After several months of careful testing these methods were abandoned. The inconsistency in the laboratory tests and the desire to obtain a test under as nearly service conditions as possible suggested the desirability of a long time test between pipes underground. Such a test was carried out in which eight pieces of commercial wrought pipe and three pieces of lead pipe were buried

FIG. 2—THE LEAD PLATES AFTER WASHING

in a ditch about three feet under ground. These pipes were arranged in pairs placed eighteen inches apart. One pipe of each pair was attached to one terminal of a transformer and the other pipe to the other terminal. The transformer gave 25 volts at 25 cycles and remained connected continuously for one year.

An additional pair of wrought pipes and one of the lead pipes were placed a slight distance from the others and left without any electrical connection in order to note any corrosive action that might

result from chemical action alone. The ends of all of the wrought pipes were covered by cast iron caps and the ends of the lead pipes sealed by wiped joints so as to prevent any possible action on the inside of the pipes where it would be less easy of inspection.

The place selected for burying the pipes had a soil similar to that of an ordinary city street. A chemical analysis of a sample of the soil removed from the bottom of the ditch in which the pipes were placed gave the following result:

Water	20.430	
Silica	54.264	in clay ground
Alumina	21.061	" " "
Iron Oxide	2.692	" " "
Lime, (Ca. O.)	.532	combined not as carbonate
Calcium Chloride	.755	0.49 per cent. chlorides
Free Hydrochloric acid	.022	
Alkali as K_2O	.210	combined as clay
Organic by ignition	.056	
	100.021	

The ground in which the pipes were placed was exposed to all changes of the weather. Current readings at various times showed from three and one-half to seven amperes, depending upon the condition of the ground as to moisture.

At the end of the test the pipes were removed, care being exercised that no damage was done to the pipes, as accurate weights after their service test for a year, were desired.

The difference in weight noted was in some instances more and in others less than found for the pipes subjected to the corrosive action of the soil only. On the average it was about the same both for the iron and the lead pipes. A chemical analysis of the soil surrounding the pipes and about one-half an inch from the pipe surface showed no material change from that of the samples analyzed before the test. There was no lead present in the earth near the lead pipes and there was no increase in the amount of iron present near the wrought pipes.

In appearance there was little or no difference in the wrought pipe between the samples submitted to the action of alternating current and those subject to the action of the soil alone.

In the samples of lead pipe there was a slight change in appearance. There seemed to be places where an accumulation of some material had built up locally on the surface.

Examination under a powerful glass failed to throw any light on the character of the formation. When it was picked off the lead beneath semed to be unaltered. There was no pitting noticeable and aside from the peculiar lumps the lead samples were unchanged.

A pair of wrought pipes was buried in the ditch from which the samples just described were removed and was subjected to the action of direct current at 20 volts for only two weeks.

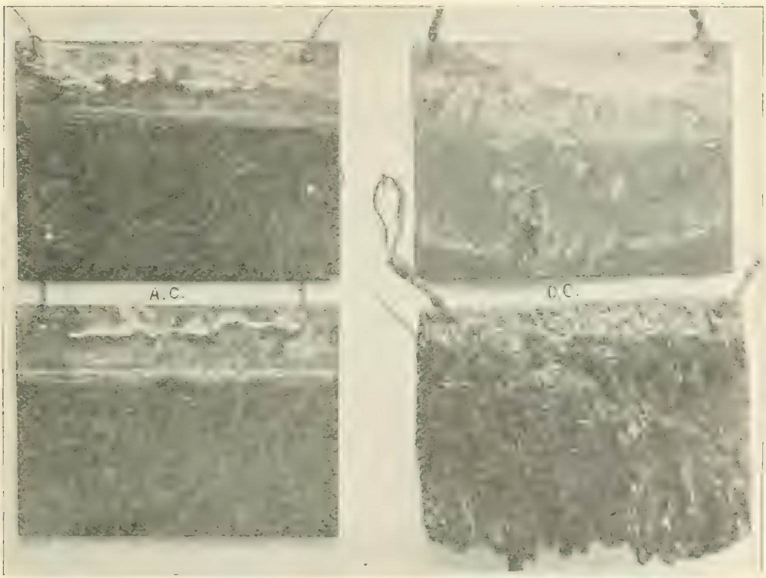


FIG. 3 THE IRON PLATES JUST AS THEY APPEARED AFTER BEING RAISED FROM THE JARS

When removed the pipes were found to be quite badly pitted. In a number of places the iron was removed to a depth of one sixteenth of an inch. Several sets of photographs of the pipes used in this test were taken but they fail to give a true impression of the actual appearance of the pipes.

In order to get a direct comparison of the action of alternating current and of direct current the following test was made. Plates approximately six inches square were placed in jars containing a very weak solution of salt water. Just enough salt was added to get five amperes to flow without excessive heating. The plates were subjected to the action of a five ampere current for six days. At the end of that time it was necessary to discontinue the test as

nearly all of the lead plates had disappeared. Fig. 1 shows the lead plates just as they were removed from the jars. Fig. 2 shows the same plates after the salts and accumulations were carefully washed off.

The appearance of the mild steel plates just as they were removed from the jars is shown in Fig. 3. The white material near the top of the plates is an incrustation of salt.

After washing off all accumulations the mild steel plates appeared as in Fig. 4.

All the edges of the plates subjected to alternating current re-

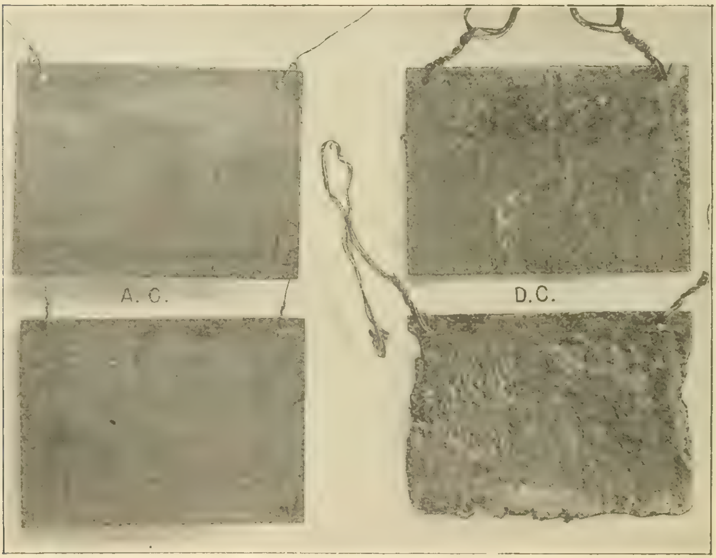


FIG. 4—THE IRON PLATES AFTER WASHING

tained their original sharpness. These plates were all apparently in better condition than the anode or gain plate in the direct-current set.

Chemical analysis of the sediment that formed in the bottom of the jars in which the iron plates were subjected to the action of alternating current showed practically the same as that in another jar in which plates had been in the acid without being subjected to any current, while there was a noticeable difference between these and the sediment in the jars which had been used for the direct current test.

It is believed these tests represent extreme conditions such as would tend to aggravate any action that would prove detrimental to pipes, and the fact that no material change in weight or appearance was found is quite reassuring.

While certain laboratory tests extending over short periods of time may indicate trivial losses due to alternating-current electrolysis, the results of this long time test made under conditions approximating those met in service show quite conclusively that if there is any action it is very small.

A 70 000 VOLT TRANSMISSION LINE

CHAS. F. SCOTT

IF we consider both high tension commercial service and time, I believe we must accord to Mr. Gerry the honor of having operated at the highest voltage over the longest time. He has been operating nominally at 50 000 volts, but actually at 55 000 volts in continuous commercial service for two years and a half. His line is about sixty-five miles from the power house of the Missouri Power Company, near Helena, to Butte, Mont. Other plants have operated at a little higher voltage; others have operated at longer distances, but taking all together—high voltage, length of time, continuity of service, amount of power—his plant may be taken as one of the foremost, if not the foremost example of high tension transmission at this time. I believe he told me that he had not lost an insulator through breakdown on the line due to electrical causes.

The foregoing paragraph is my comment taken from the Transactions of the International Electrical Congress, September, 1904, in the discussion of papers upon high tension lines. I had visited the plant of the Missouri Power Company during the preceding month.

A year later I again visited Helena and made specific inquiry as to the operation of the system during the year which had elapsed since I had been there before. I found that the record of the plant for the year has been a remarkably successful one. The service is for twenty-four hours a day, seven days a week, and the power delivered at Butte for mining and smelting operations shows a very high load factor. There had been a few interruptions, due to the high voltage system. These were four or five in number; one had occurred in the sub-station, and was a discharge between line and ground across an apparatus terminal which had been recently installed. The discharge, however, did not cause a short circuit and the service was not interrupted. There were several line short-circuits, which were attributed to lightning. When this occurred, the circuit at the power house was opened and immediately closed again. The resulting inconvenience was simply the restarting of such of the motors as had stopped as the result of the momentary interruption.

The users of this power have found that it is more reliable than steam power generated on their own premises.

The endorsement of the success of this plant, both from its commercial and electrical standpoints, is proved by the present plans for extension. A new dam and power house will be constructed a few miles below the Canyon Ferry plant. The old and new power houses will be operated in parallel over the present lines to a new sub-station at Butte and an additional sub-station at Anaconda.

The transmission voltage will be increased to 70 000 volts at the power houses, and new transformers are to be installed in the old power house for the higher voltage. The maximum distance of transmission will be approximately 100 miles. There are at present two pole lines which will be used for the higher voltage.

The additional lines, which will join the two power houses at one end and the two sub-stations at the other end, will employ insulators of the same kind which have been used, although the pins will be increased slightly in length.

The new power house will contain three banks of raising transformers, each consisting of three 2 000 kw units; two of these will be for regular service, and the additional one will be available as reserve, also for use in line tests, and further may become a part of the regular working equipment when additional generators are installed.

An important adjunct to the system will be a steam turbine auxiliary plant at Butte. During seasons of low water the steam plant will be used to supply power; at other seasons, when water power is abundant, and the limit of the amount of power transmitted is the capacity of the generators and tranmission circuits, the turbo generators will be uncoupled from the turbines in order that they may run as idle synchronous motors for increasing the power factor of the current from the transmission lines.

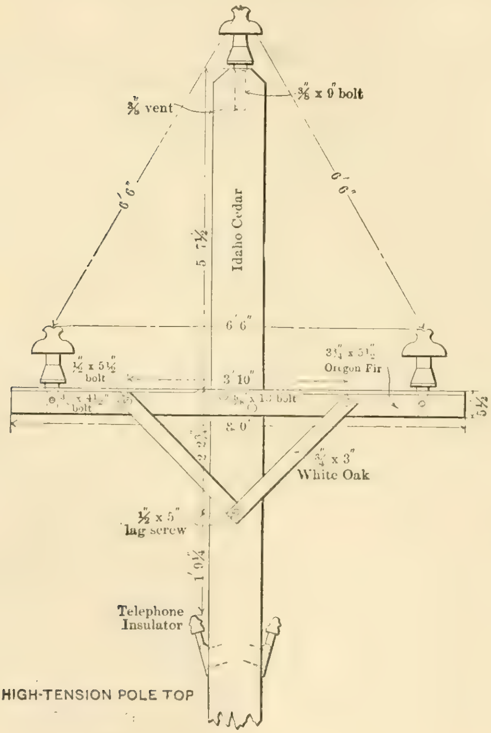
The contracts for the electrical equipment of the new plant have been placed with the Westinghouse Company, which furnished the apparatus for the first plant.

The particularly interesting feature of the new plant is the adoption of a higher voltage than has ever been employed commercially by the engineer who already holds an enviable record for operating at high voltage. It also is of interest to note the form of construction used.

A brief description of the insulators and pole construction,

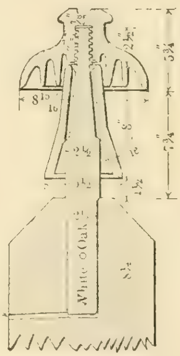
which have been found so well adapted to conditions in Montana, is given in the following extract from a paper before the International Electrical Congress by Mr. M. H. Gerry, Jr., who has had under his direction the engineering of the early plant and of the extensions which are being made by the new company, the Helena Power Transmission Company:

As a further illustration of current practice, the high ten-



HIGH-TENSION POLE TOP

FIG. I



SECTION OF
HIGH-TENSION INSULATOR,
SLEEVE, PIN, AND POLE TOP.

FIG. 2

sion of the Missouri River Power Company, built under the direction of the writer is here briefly described.

This transmission has been in service for over three years, operating at 57 000 volts, delivering power at a distance of over sixty-five miles in a satisfactory manner. The country through which it passes is very rough.

The lines leave the generating station at an elevation of about 3 700 feet, pass over three distinct summits, including the

Continental divide, at which point they reach an elevation of 7 300 feet above sea level. There are two parallel lines extending from the generating station on the Missouri River to the Butte substation.

They are located, in the main, on a private right of way 200 feet in width, from which all timber was removed. Each of the lines carries three copper cables, arranged in a triangular position, seventy-eight inches apart. The cables are composed of seven strands and have an area of 106 000 circular mils. Fig. 1 illustrates the upper part of a standard pole. Fig. 2 is a section of the insulator, sleeve, pin and pole-top.

The poles are of Idaho cedar, the cross-arms of Oregon fir, the braces and pins of white oak, and the insulators and sleeves of glass. The cross-arms, braces and pins are held in place by means of through bolts. The pins in the top of the poles are of larger size and of greater length than those in the cross-arms, to provide for the greater strains there present. The pins were prepared by being first dried and then treated in paraffine, until all moisture was removed, and were then tested to 60 000 volts. The glass sleeves are not fastened to the insulators and merely rest on a shoulder of the pins.

The circuits are transposed five times, making two complete turns between the generating station and the sub-station. The switching arrangements are such that the circuits may be operated either singly or in multiple. A telephone circuit is located on one of the lines and gives good results in service. The poles are from thirty-five to seventy-five feet in length, and the pole-tops are from nine to twelve inches in diameter. The poles are set from six to eight feet in the ground, according to height, and the standard spacing is one hundred and ten feet, with a maximum spacing of one hundred and fifty feet.

Note.—The illustrations, Figs. 1 and 2 are reproduced through the courtesy of the American Society of Civil Engineers.

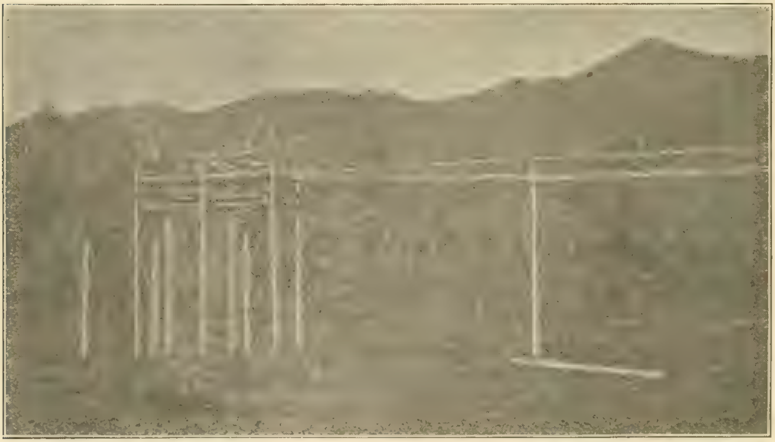
POWER TRANSMISSION AND LINE CONSTRUCTION IN THE WEST*

ALLAN E. RANSOM

Electrical Engineer, Lewiston-Clarkston Company, Clarkston, Washington

THE Lewiston-Clarkston system at the present period consists of two power stations with a combined steam and hydraulic capacity of 1 500 hp and fifty miles of transmission lines, with secondary distributing systems and substations in five towns and extensions under construction to several other towns in the Palouse country.

Power Station No. 1 is situated on Asotin Creek seven miles from Lewiston-Clarkston and one and a half miles above the town of Asotin. The irrigation flume of the company furnishes the



SOUTH TOWER, SNAKE RIVER SPAN, LEWISTON-CLARKSTON COMPANY. CLARKSTON SIDE

Similar construction to north tower except there are no flexible connections. The wires come in straight to the insulators from the higher elevation.

power used at this station and winds around the valley for seven miles. This flume was designed for a capacity of one hundred and twenty-five cubic feet per second and is used for power and irrigation. The plans of the company contemplate building a flume at some three hundred feet greater elevation and constructed of

*Paper presented before "Pacific Coast Electrical Transmission Association," ninth annual convention, Portland, Oregon, June 29-30, 1905.

concrete. By thus increasing the head and capacity, the development of a new station of 2 500 hp capacity becomes possible.

In the present hydraulic station much satisfaction has resulted from the use of the Tirrill regulator, and the charts shown illustrate the great difference in the regulation of the system by the use of this device. The papers presented at the last annual convention, by Mr. Hutton and Mr. Lighthipe, as well as the highly satisfactory experience of the Washington Water Power Company, at Spokane, led us to adopt this, and the results are as represented. The saving on lamp renewals, we estimate, will pay for the device in a short time.

The Lewiston substation contains three 200 hp capacity transformers and is connected with the Clarkston auxiliary steam sta-

TRANSMISSION LINE, LEWISTON-CLARKSTON COMPANY

tion by a three-wire 0 000 circuit. By means of the Tirill regulator in each station, we can keep the regulation at a very close point.

The Clarkston steam auxiliary station, designed by William Wheeler, a consulting engineer, of Boston, as illustrated, is built in accordance with the most recent engineering experience. The equipment therein consists of a 500 kw (tested to 1 200 kw) Westinghouse-Parsons steam turbine equipment operating at 2 300 volts, 60 cycle, three-phase. The station is built of concrete and steel and is divided into two large rooms, the boiler room containing the boilers, feed pumps and induced draft apparatus, and the other room containing the engines, generators and high tension transformers.

The Palouse county transmission lines enter this station

through a bank of three 200 kw raising transformers. The towns of Genessee and Moscow, eighteen and twenty-six miles respectively distant from Clarkston, are supplied with power at 22 500 volts. The transformers are so designed that they may be connected up for 22 500 or 45 000 volts delta. The transmission line is designed for operating voltages up to 60,000 volts; a number of the features of its construction are shown in the sketch.

The pins used are a composite pin, the arm pin being designed by Mr. D. L. Huntington of the Washington Water Power Com-

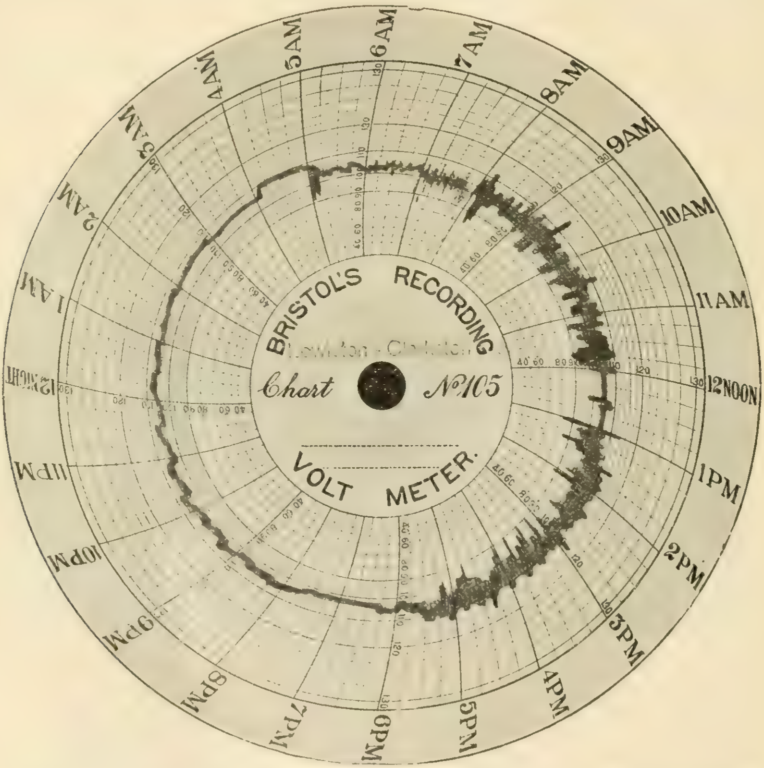


CHART SHOWING VOLTAGE REGULATION BEFORE INSTALLING TIRRILL REGULATOR

pany, of Spokane, and being made one and a half inches shorter than the pin used on his system. The top pin was designed by the writer after a careful examination of all top pins used on various lines throughout the country, and so far has proved very satisfactory. A number of bending tests of the pins adopted was made, with the results that the top pin bent under a weight of 738 lbs.,

and the arm pin under a weight of 984 lbs., which indicate ample strength for all purposes of line construction. The top pin as constructed weighs eight pounds and costs forty-six cents a pin, f. o. b. Lewiston, being a welded pin of iron and steel. The arm pin weighs eight and a half pounds, has a base of cast iron around the steel, and costs thirty-six cents, f. o. b. Lewiston. We have had

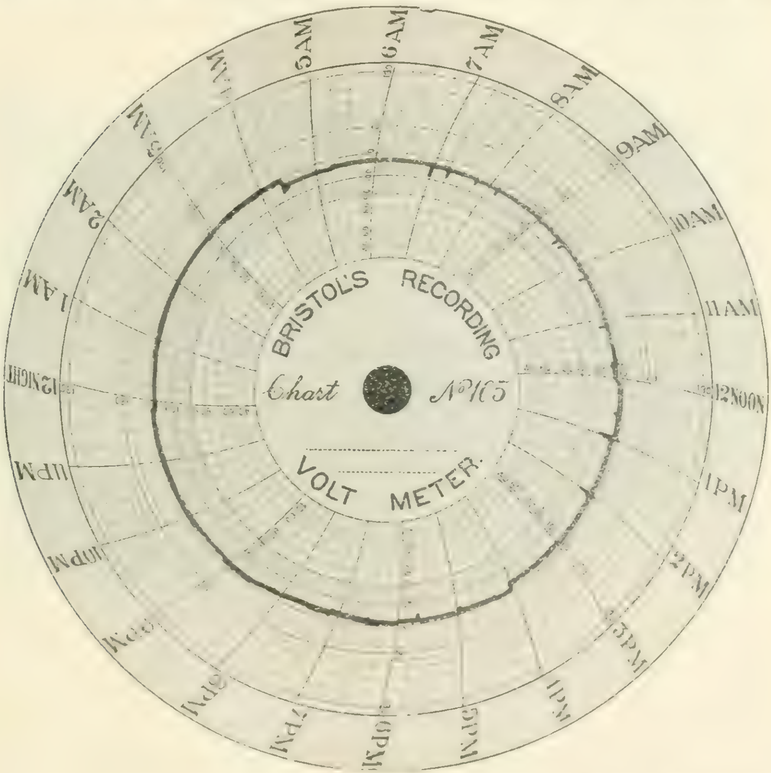


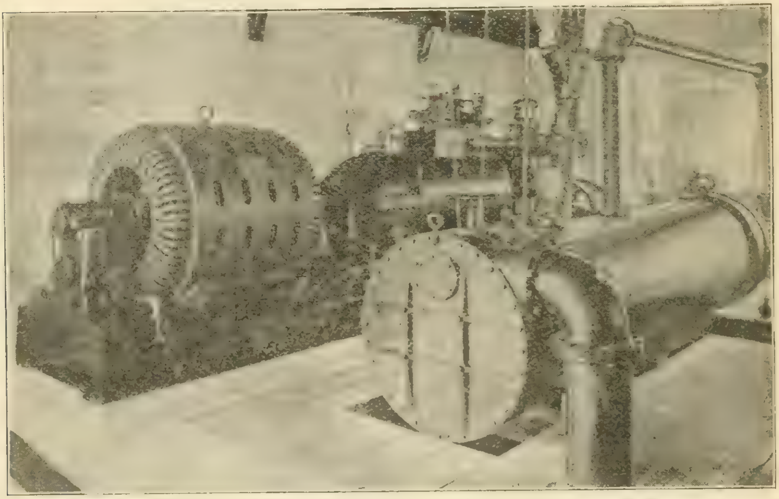
CHART SHOWING VOLTAGE REGULATION AFTER INSTALLING TIRRILL REGULATOR

over 5 000 of these pins in use on the transmission line in the last ten months and have had none to replace. The spacing of forty-eight inches on the transmission was adopted after considering the various lines in operation, and has been adopted throughout the transmission.

THE TELEPHONE LINE

The telephone line, composed of two No. 14 B. and S. guage telephone wires on cross-arms and glass insulators and

situated five feet below the transmission line, is transposed every five poles, and we have had no trouble from induction or other causes. Each telephone is protected by a high tension fuse outside and a small lightning arrester at the phone. At the present time we are experimenting to find the best gap to use on the lightning arrester, as we have experienced some difficulty in connection with the ground wire on some of the arresters. Any ground on the system makes it almost impossible to talk over the line at all. With the line perfectly clear, we have had no



500-KW PARSONS TURBO-GENERATOR, WITH ALBERGER SURFACE CONDENSER, AT THE CLARKSTON AUXILIARY STATION, LEWISTON-CLARKSTON COMPANY

trouble whatever with the 1 600 ohm telephone of the Stromberg-Carlson type.

THE TRANSMISSION LINE

The main transmission line as at present constructed is composed of three No. 4 B. and S. guage wires supported by twelve pound double petticoat insulators of the Thomas No. 50 type.

In the first three miles out of Clarkston, the line crosses the Snake river over a 2 000 foot span, and ascends the Uniontown Hills at an elevation of 2 000 feet in this distance. The construction of the span of the Snake river brought in several elements as to wind pressure and variations of temperature. The construction of the span illustrated herein, may therefore be of interest. The span consists of five wires arranged as shown in illustration, composed of No. 4 B. & S. hard drawn copper wire of a breaking

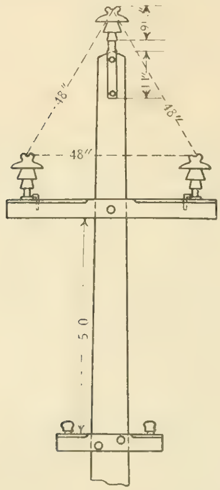
tension of 1967 lbs. These cables are strung with a tension of 700 lbs., and one tower being much higher than the other necessitated a special flexible connection to prevent the breaking of the wires due to the abrupt angle due to higher elevation at which the north tower was placed. The flexible connection as shown has proved satisfactory and for the use of which we are indebted to a suggestion made by Mr. K. G. Dunn, of San Francisco. As neither ice nor sleet is prevalent in this section, this element has not entered into the construction of the span. The span as at present constructed is successful. We have had several wind storms varying from forty-five to sixty miles an hour and temperature variations of from 10° to 90° F. during the four months that these wires have been strung. The current has been carried continuously for some sixty days and no trouble has been experienced. The same has been true of the entire transmission line, and, except for a few insulators, it has not been necessary to make any repairs on the line. The continuous operation of twenty-four hours a day has not been interrupted. Several severe electrical storms have been experienced, but the arrester equipment at the stations has proven good protection.

GENESEE SUB-STATION, LEWISTON-CLARKSTON COMPANY

High tension wires enter through 18-inch tile. In each tile is a circular plate of glass one-fourth inch thick, with a one-inch hole drilled in the center.

In connection with this system the municipal pumping has become quite a feature. The municipal pumping station at Lewiston, is the largest electrically driven plant in the northwest. The installation consists of a 200 hp. 2000 volts, three-phase, type C induction motor, connected by a gear to a Dean triplex pump of a capacity of 114000 gallons an hour, pumping to an elevation of 345 feet. The city has two reservoirs, one at an elevation of 220

feet and the other at an elevation of 345 feet. This pump has been in operation for nearly two years and has proven very successful. The city of Genessee has also installed a pumping station on a smaller scale, lifting the water 150 feet by means of a Gould triplex pump, belt connected to a 20 hp induction motor, the pump capacity



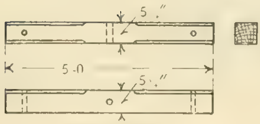
STANDARD LINE CONSTRUCTION

LEWISTON-CLARKSTON COMPANY.

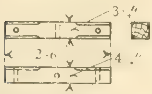
June 1, 1905.

Material required per pole.

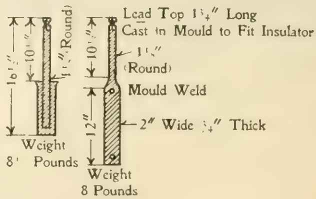
1 Main & 1 telephone cross arm.
3 high tension insulators-Thomas 50 B.D.
1 Special pole top pin.
2 Special main cross arm pins.
2 glass telephone insulators.
2-2"-Locust telephone pins.
2-5/8" x 10" sq. hd. Machine bolts with nut and one washer for pole top pin.
1-5/8" x 16" sq. hd. machine bolt with nut and two washers for main cross arm.
2-3" x 1/4" Rt. angle lag screws.
2-1/2" x 7" lag screws with one washer.
Paint pole butts, gains and tops with "Conservo".
Standard 35' pole 8" top-Idaho Cedar.



Main Cross Arm



Telephone Cross Arm



Special Composite Pins

being about 20 000 gallons per hour. Moscow will soon be similarly served.

The wood-finish mills of Lewiston and Clarkston, as well as the machine shops, are driven entirely by induction motors of from five to fifty hp capacity which have proved very satisfactory as a source of power.

The construction of an electric railway is now assured, which will furnish a market for power for this purpose. In view of the rapid growth of power business in this section, plans and investigations are now being made for the development of an additional

8 000 hp on the Grande Ronde river, thirty-six miles distant. The development of a transmission business in a rapidly growing country produces the inevitable demand for the development of all water powers available. And in this section the prospects for a large and varied application of electric power makes it one of great interest.

The writer is indebted to Mr. Edgar H. Libby, president and general manager of the Lewiston-Clarkson Company, through whose courtesy the information and illustrations herein presented, are given.

ENGINEERING AND THE COLLEGE GRADUATE

H. W. BUCK

Electrical Engineer, Niagara Falls Power Company

WHEN one considers the large number of students enrolled in the technical schools it is surprising to find how comparatively few subsequently follow the practice of strictly engineering work. Perhaps the majority of graduates are greeted early by experiences similar to mine, and being disgusted with the outlook in the profession have gone into other lines of work. When I left college and had "passed" my last examination I felt that I was at least moderately supplied with learning, and held within myself a sense of assurance that my diploma was like a stock certificate or other security from which I could immediately begin to draw a large financial return in dividends. I then entered the portals of the world, and found that my services in the open market were worth just $4.50 per week! The shock was a violent one, but with it came a great lesson, a lesson which all of us should learn, that the years spent at college did not make engineers of us and that no college course alone can make a man into an engineer.

It is not intended here to belittle the importance of the college training, but to bring out the point that the undergraduate work is simply a preliminary step. It serves only to lead a man's mind into accurate and systematic habits of thought, which enables him afterwards to readily grasp the special knowledge required in the particular occupation which he has taken up. Very few men ten years after graduation could "pass" examina-

tions in many of the technical subjects which they studied at college, however competent they may be in the practice of the engineering profession; but the strenuous efforts in undergraduate years, in connection with those subjects, have unquestionably helped them in their subsequent careers. It is in this way that the real benefits of the college training are attained.

The college examination, with all its disadvantages, abuses and claims laid against it, is especially good training for the engineer. The practice of engineering involves much work which is similar to "cramming" for a college examination. A report, for instance, is required from an engineer, at short notice, upon a proposition with which he is not familiar. He must set himself to the task of studying the subject at high speed and "cramming" himself with its essentials. The engineer must then set down in writing clearly, so that others can understand it, a comprehensive statement of what he has learned about it. The operation resembles closely a college "final." If a man is to be a successful engineer all such examinations must be "passed."

Although comparatively few graduates of technical schools or colleges afterwards follow strictly engineering work, a much larger number engage in work in which a general knowledge of technical subjects is of great value, such as in the manufacturing arts. I am a strong believer in scientific and technical education, whether a man is to be an engineer or not. Modern life stands essentially upon a technical basis, however unattractive this proposition may appear to the classical idealists from the academic courses. This condition grows stronger every year, and in the struggle for existence the man with the geometric temperament, so to speak, is likely to win out in the long run. It matters not whether the situation is a broken-down automobile, an investment of capital in industrial enterprise, a surgical operation or a battlefield, the ultimate relation of things will probably be found to be largely a problem in science, engineering or mechanical economics.

All of this is encouraging for the future of the engineer. It means that his position as a member of society must become more and more indispensable, and that in the end it must be a dominating one. Even in the life of to-day, for example, all our methods of transportation, transmission of power and intelligence and of manufacturing are the fruits of the scientist in combination with the engineer, and latterly even the farmer has been rapidly

casting aside the traditions of his ancestors and yielding to this inevitable influence. Practically every operation in which man is now engaged involves directly or indirectly the work of the engineer. The title "engineer" should, of course, be taken in its broadest sense. Engineering is required as much in the design of a pianola as in that of a power house.

The status of the engineer in society to-day is nevertheless far from commensurate with that which mankind owes to him. In the economic order of things, the engineer does not receive a reward in proportion to his contribution to man's work. This is perhaps largely the fault of the engineer himself for belittling his own importance and for not holding himself up to the dignity of his position. It is for those of us who have followed the engineering profession to use our influence toward raising its standing up to a recognized equality with the older professions.

To the popular mind the title of "engineer" has only a vague meaning. As generally understood, a mechanical engineer is a mechanic who must necessarily carry a lunch pail and wear overalls. Similarly the electrical engineer is a man who tends dynamos or repairs front door bells, and a civil engineer is a man who either spends his time carrying striped poles around a field or else in bossing a gang of "dagos" digging a ditch. These examples are not exaggerated, but represent truly the general sentiments of people in regard to the profession of engineering. This is a manifest injustice, and every engineer should help uplift his profession by the high class of his work and by educating the world at large into an appreciation of its importance.

Engineering is more of an exact science now than it was in the rule-of-thumb days of fifty years ago, and many of its branches have already reached a stage of almost astronomical precision. It is for this reason that a systematic mental training in technology, before entering engineering practice, is so desirable. The men of the future who will occupy the leading positions as engineers will probably be those who have had a college training and have taken the best advantage of the opportunity.

A CONVENIENT TRANSFORMER SET FOR TESTING INDUCTION MOTORS

R. A. McCARTY

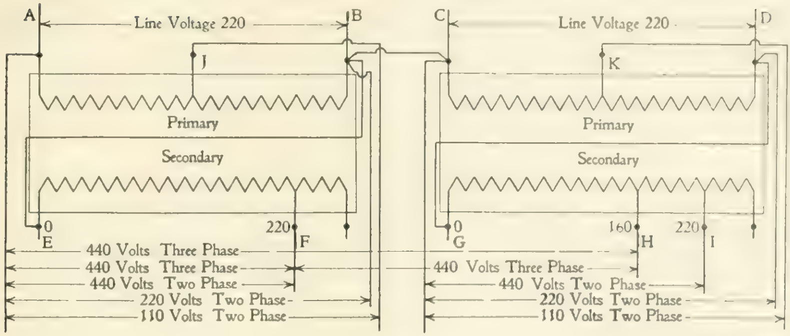
IN testing induction motors in large numbers it is very desirable to run a number at the same time. Obviously the problem lies in securing different phase and voltage combinations simultaneously from two or three single-phase transformers and running a number of motors from the same set of transformers.

Where six or eight different combinations may be needed it is evident that much time will be wasted if it is necessary to change transformer connections each time a new phase and voltage combination is wanted. Economical testing requires that as many motors as possible be tested simultaneously, a thing which would be impossible with a reasonable number of transformers, without some such arrangement as here indicated.

The arrangement of the different transformers and the different voltage taps brought out is described in the May, 1905, JOURNAL, p. 321. Assuming a line voltage of 220 volts, two-phase, the accompanying figure indicates the phases and voltages that may be secured from two single-phase transformers. The upper part of the figure shows the connections as they are made on the transformers referred to. In the lower part of the figure the same connections are shown but given in the more usual diagrammatic form for two-to-three-phase transformation. Two other transformers may be arranged to convert to 220 volts three-phase as shown in Fig. 80 of the May JOURNAL, p. 322. The combinations available from these four transformers will be seen to cover the majority of cases.

The ratios of primary voltage to secondary voltage will hold of course if other voltages, such as one hundred, two hundred and four hundred are desired, and these may therefore be obtained by varying the impressed voltage so as to give the desired secondary voltage.

In some instances, where all the combinations are working at



one time the voltage delivered at the terminals of some of the machines may be slightly above or below the rated voltage, or slightly unbalanced, but the regulation is sufficiently accurate for any commercial testing.

EXPERIENCE ON THE ROAD

SOME NOTES ON SOLDERING

I HAD not been long out of college when I was first sent out as a road engineer, so it was not to be expected that I would know very much. In those days, I even thought that a soldering iron was made of iron.

When I first used a soldering iron on wire joints, I held a dry iron under a joint and waited for the wire to heat enough to melt the solder placed upon it. After floundering around at that awhile and making a bad job of it, I began to remember how I had seen others do it, and then I placed some solder on the iron and held the iron with the molten solder against the joint, which soon began to sizzle, and as it was clean and well fluxed, the solder flowed at once all through and over it.

In college, I had taken a course in physics under Professor N. and had heard all about conduction, convection and other things concerning heat, and also knew that copper is a good conductor of heat. But it did not occur to me, in the present instance that those principles had anything to do with the work in hand. After I had mastered the job, I began to see their connection with it.

A soldering iron, when in use, may be considered a reservoir of heat and the object in view is to get as much of the heat as possible into the wire. When the iron is held against the joint it touches only the high spots and there is a thin film of air between no matter how smooth the surfaces may be. This air is a very good heat insulator, though when solder is run into this space, it unites with both iron and wire and acts as a bridge over which by the principle of conduction heat flows rapidly into the wire from the reservoir.

Clean and *hot* are the two essentials. One trouble with some novices is that they only half appreciate that statement and seem to have an idea that the solder is the only thing requiring heat, whereas all surfaces to be joined must be brought to the temperature of molten solder before union can take place. This mistaken idea does not lead to much difficulty when the

work is confined to joining small wires, for in that case, a small quantity of molten solder contains sufficient heat to quickly raise all parts of the joint to the required temperature. But when large wires or any bulky pieces of metal are to be soldered, this idea leads to trouble.

HEAVY CABLE TERMINALS

One of my early jobs was the erection of a low voltage generator where large cables had to be run from the machine to the switchboard. Cast brass terminals were to be soldered on the ends of these cables and I set some men at this task. These men were local workmen who had applied to me for work and they were fairly good mechanics along certain lines, but they were not accustomed to soldering. When I returned to the work after a short absence, my suspicions were aroused by the rapidity with which it was progressing, so I gave one of the soldered terminals a few raps with a hammer whereupon it promptly fell off. The men had heated the solder and terminal all right but had not heated the cable sufficiently to keep it from freezing the solder when inserted into the terminal, and after that they had not applied a torch to the terminal long enough to sweat the solder into the cable. Also the inside of the terminal had not been properly cleaned and tinned; so the solder was not adhering very well to that.

I soon found that sweating the solder with a torch after the end of a large cable is placed in a terminal is not very satisfactory because the application of heat is so slow that there is time for the rubber insulation to burn. Furthermore, the workman cannot see when the proper temperature is reached inside the terminal. The methods described in the JOURNAL for January and February, 1905, are the proper ones to follow. In addition, it is well to have some water and a bunch of waste handy to quench the joint when the parts are in place and the heat has done its work. This is because large cables and terminals cool slowly and if a workman is holding the cable in position he is liable to move it unintentionally when the solder is nearly set and break the continuity of the solder. Quenching solidifies the solder at once and avoids this danger.

BAR WINDINGS

When our company put out the first bar-wound armature, I was detailed as erecting engineer and instructed to put

on the winding during the erection of the generator. The joints between armature bars and end connectors were fastened by two filister head brass screws and nuts. It was decided that these joints should be soldered and it was up to me to say how this should be done. The men I had to help me were selected from those who daily came to the plant looking for a job and they did not know any more about soldering than I did. The heads of the screws on one side of the joints and the nuts on the other prevented a soldering iron from making a contact with any considerable portion of the surface and I did not realize at that time what a large quantity of heat could be drawn into the joints from an iron through a small bridge of intervening solder. Furthermore, the small pointed soldering iron furnished with a roadman's kit of tools was of neither the right size nor shape to do the job with.

A gasoline torch seemed to be the most convenient thing to use but the torch flame spread out and charred the insulation. Some thin sheet asbestos was then procured and cut into various shapes and placed around the joints so as to expose them to the flame, while shielding the insulation. This scheme worked well; so several torches were secured and the work rushed through. We thought that we had done the job very cleverly and, all things considered, in the best possible manner.

BAR WINDINGS AGAIN

Several years afterward I was again called on to take charge of the electrical end of the erection of a large bar-wound alternator in another city. In the intervening time I had been away from the factory almost continuously and had made no observation of the newer methods employed in winding bar-wound armatures. When the winding material arrived, I bought a roll of sheet asbestos and started to borrow all the gasoline torches in the neighborhood preparatory to soldering the joints. But, in this instance, one or two of the local men employed to assist in putting on the winding really knew something about soldering. They had never taken a course of lectures on heat but they were good artisans and had seen bar windings put on since I had. They called my attention to the fact that the joints between the bars and end connectors were fastened by screws with countersunk heads instead of filister heads. This allowed a soldering iron to touch the entire surface of one side of a joint.

The men discovered a couple of soldering irons somewhere about the plant that had been made for similar work. These were thick, chunky affairs about as broad as they were long, having ample heat capacity and they were made wedge shape instead of pointed.

This method was much easier than building an asbestos shield around each joint; so, as the job was in a rush (and they usually are), the next thing to do was to get plenty of soldering irons. Fortunately the plant was in a large city where bar copper of almost any standard cross section could be bought and coppersmiths could be found to make them into soldering irons. Enough irons were made to keep four men at work. Two men were placed at each end of the horizontal diameter of the armature, the two on each side working at opposite ends of the same bars. Behind each pair of men was a furnace for heating irons, and there were irons enough so that no one had to wait. At intervals the armature was rotated slightly in its bearings, so that the workmen might always be working in the most advantageous position and the rapidity with which the job was done made the old method with gasoline torches and asbestos shields seem as like a canal boat speeding with a through freight.

This experience taught me something that is well for young engineers to bear in mind. It is this: when a man has found a good way of doing a new thing, if it is a thing that will be done many times in various places by different people, he should reflect that some one, somewhere in the world, is likely to have found a better way of doing it. Let him also think over the method in contemplation. Some slight variation either present or potentially possible may as in the case last cited simplify the procedure.

CALCULATING TEMPERATURE RISES WITH A SLIDE RULE

MILES WALKER

A SIMPLE and accurate method of calculating changes of resistance of copper with changes of temperature, and vice versa, can be employed by using a slide rule fitted with a suitable sliding scale. The method here described takes into account the changes of temperature coëfficient with temperature.

The scale for this purpose can be laid out on any part of the slide that is not required for ordinary work, as on the reverse side of the sliding stick; or a new slide may be made for the purpose. To construct the scale, if the old slide is used, rub out the scale that is not wanted with fine sandpaper and repolish. Place the slide in the rule so that this clean surface will be opposite the left-hand end of the lower scale. Then opposite 1.0 make the first division of the new scale and mark it 0°. Opposite 1.039 make the second division and mark it 10°. (These division marks can be conveniently made with the point of a sharp penknife and afterwards filled in with India ink.) Opposite the point 1.0797 make a third division and mark it 20°, and so on up to 100°, according to the following table:

TEMPERATURE COEFFICIENTS OF COPPER

Temperature in degrees—Centigrade.	Temperature Coefficient K.
0	1.0
10	1.03929
20	1.07968
30	1.12107
40	1.16332
50	1.20625
60	1.24965
7c	1.29329
80	1.33681
90	1.37995
100	1.42231

The scale may be sub-divided into 5° divisions, or even single degree divisions if desired. It will then resemble the upper scale shown in Fig. 1.

Example—A coil of copper wire whose resistance is known to be 410 ohms at 20°.

If it is desired to find the temperature of the coil when its resistance has risen to 440 ohms, adjust the slide so that the 20° mark is opposite the 410 mark on the fixed scale, as shown in Fig. 1. Then opposite 440 will be found 39°, the temperature corresponding to the resistance. Thus the temperature rise is 19°. Moreover, one setting of the slide reveals at a glance the resistance of a coil for any temperature between 0° and 100°. For instance, at 70° the resistance is 491 ohms; at 80° it is 508 ohms.

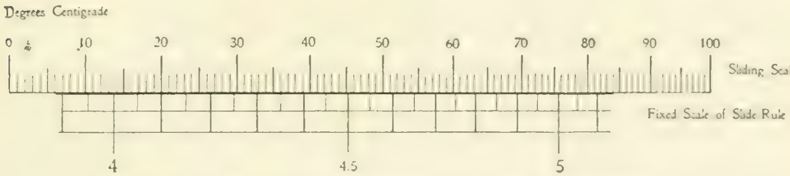


FIG. 1—NEW SCALE CONSTRUCTED ON NEW SLIDING STICK

If it is not desirable to rub off any of the regular scales, a scale not quite so accurate may be laid off by using some of the graduations on the scale of a Faber slide rule. To do this place the slide in the rule with the tangent scale next to the lower fixed scale, and place the point 23° 30′ on the slide opposite 1.0 on the lower scale, as shown in Fig. 2.

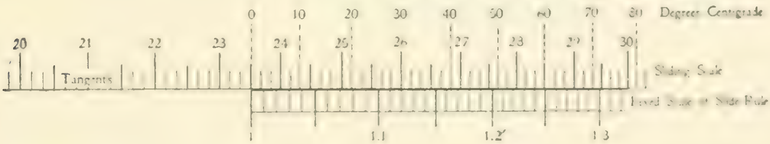


FIG. 2—NEW SCALE CONSTRUCTED ON OLD SCALE OF TANGENTS

In this position it will be found that every fifth division line on the tangent scale very nearly coincides with the points 1.039, 1.079, etc. These divisions accordingly may be fixed by marking the 23° 30′ line as 0°, the 24° 20′ line as 10°, the 25° 10′ line as 20°, etc., each 5° of the old scale corresponding to 10° of the new. That this scale may be used in this way is only a coincidence, since there is no natural relation between the scale of tangents and that of temperature coëfficients.

A theoretical explanation is offered here in a general way, in order that the same principle may be applied to the construction

of other scales. Let $R_1 =$ resistance at T degrees, $R_0 =$ the resistance at zero degrees, a = the temperature coëfficient of resistance for copper. Then the increase of resistance with temperature may be represented by the formula $R_1 = R_0 + R_0 a T_1$.

Hence, $\frac{R_1}{R_0} = 1 + aT_1$, which is constant for a given T, and the expression may be written

$$\frac{R_1}{R_0} = K_1 ; \text{ similarly, } \frac{R_2}{R_0} = K_2$$

Dividing, $\frac{R_2}{R_1} = \frac{K_2}{K_1}$. This evidently holds whatever may be the law of change of K with change of T, so that

$$\log R_2 = \log R_1 + (\log K_2 - \log K_1).$$

The divisions on the scale constructed are proportional to $\log K_1$, $\log K_2$, etc., and the divisions on the lower scale in Fig. 1, are proportional to the logarithms of resistance, so that by placing one scale opposite the other, the difference between the logarithms of K_2 and K_1 can be added to $\log R_1$ and thus the logarithm of R_2 obtained.

It will be seen that this method is not at all dependent upon any proportionality between the change of temperature and the increase of resistance, and the same method can be adopted for constructing a scale which will give the flux density in iron for any given magnetizing force; in fact a scale can be constructed by which we can at once calculate one quantity from any other of which it is a one-valued function.

LINE CONSTRUCTION*

B. L. CHASE

Superintendent of Line Construction, Columbus Railway and Light Company

IN order to secure freedom from interruption, high tension lines should be constructed above all telephone, telegraph and other wires for service of a similar character, for these conductors being small, and easily broken down by wind or sleet, will cause unending trouble to both companies, and be a constant menace to life and property.

An accident of this nature came under the observation of the writer some few months ago. A broken telephone wire which had fallen across a 4 500-volt line at a point five or six miles from the power station, was lying across a fence. An Italian in attempting to remove the wire from his path was instantly killed, and his companion also killed while trying to render assistance. In this case the telephone company settled with the families for twelve hundred and fifty dollars each.

High voltage lines constructed underneath telephone, telegraph and other wires also endanger the lives of the employees of these companies, whose work necessitates their constant exposure to danger, by climbing between high-tension wires. Telephone linemen do not, as a rule, realize the importance of keeping entirely clear of the high voltage circuits, as their work is such, that all wires may be handled without personal discomfort.

Considering the enormous number of telephone and telegraph wires, and the constant work of maintaining them, it can be seen that it is imperative that the high tension lines be placed above and entirely clear of all other wires. High tension wires are several times larger, and being stronger are less liable to accident from natural causes, and the pole fixtures being much heavier and of more substantial construction, are practically immune from accident.

A good road along a pole line is very desirable, and the route selected should be as free from obstruction as possible, and trees carefully trimmed, as even the small limbs will be the cause of much trouble.

Wood poles are the most desirable for high voltage transmission, iron poles affording more chance for troublesome and dangerous grounds, and subjecting workmen to extreme danger from

*Abstract of a paper read before the Ohio Electric Light Association, Put-in-bay, Ohio, August 16-18, 1905.

the same cause. Iron poles, however, have demonstrated their utility for low voltage and railway work, and are more sightly in such cases where it becomes necessary to place them at close intervals.

For power transmission the pole should be both long and strong, in order to carry the circuits above all others and to stand the stress of heavy winds and sleet storms. All poles should be shaved, painted and gained before being erected, as the cost of labor in doing this work will be double after the pole is set on end.

For ordinary work poles should be set 120 feet apart or 44 to the mile, but local conditions will govern, especially in cities. The setting should be carefully done, and the poles kept as nearly in line as possible. Too much care cannot be taken in tamping, as a poorly tamped pole will be out of line after the first wind storm, and to straighten up, means unnecessary expense, and if left in that condition speaks but ill of the man who had charge of the work.

Hard yellow pine serves best for cross arms, and for ordinary construction will give good results, but for heavy corners and junction poles where the strain is great, oak arms should be used. Machine bolts $\frac{5}{8}$ or $\frac{3}{4}$ inch in diameter passing through both arm and pole with a large washer under both head and nut, will be found the best for holding the arm securely in the gain. This method makes a cleaner and safer job than fastening the arm with lag screws, and permits repairs and changes to be made much easier. Lag screws are cheaper, however, and are sometimes used in ordinary construction, but should be avoided in heavy work.

For high tension lines the cross arms should all be double, and a block securely bolted between the arms about eight inches from the end, will materially add to their strength. The initial cost of this mode of construction will be somewhat higher, but will be cheaper in the long run. It practically prevents a wire from coming in contact with the arm through breakage of a pin or insulator, and the resultant effects—probable burning off of the cross arm and allowing the wire to fall to the street or upon other wires strung below.

Poles at angles should always be guyed at a point as near in line with the strain as possible. A very light pole properly guyed will withstand heavy strains, without distress, which would otherwise require the erection of a heavier pole.

In all cases great care should be exercised to keep guys clear

of all other wires and strain insulators should be cut in about six feet from the pole, which will assure a greater degree of safety to employees who work among the high tension wires and the guy wires with which they might come in contact accidentally. Guying to trees is a very bad practice, for you do not know what minute they will blow down and cause you trouble that would cost more than ten times the cost of a guy stub in the first place.

The most dangerous strains on over-head lines come from sleet storms, ice sometimes covering the wires to a depth of an inch. Under these conditions the insulators and pins become the weakest points, and precaution should be taken in your construction to guard against such strains. A $\frac{3}{8}$-inch carriage bolt through the pin lengthwise will insure against a failure under almost any conditions, and will be found to be a cheap method of reinforcement. Other means for the prevention of accidents should be installed, such as iron guard wires at angles to keep wires from slipping off the arm, should a pin or insulator break.

Several head guys at corners or at the end of the line, will relieve the strain and will in case of accident to these poles save several poles from being broken.

It is the belief of the writer that only in a case of emergency, work should be done on circuits of this nature while current is on the line, for it is extremely hazardous at best, and the method to be preferred is to complete all arrangements and cut the current off only long enough to make actual connections.

The different circuits should be so arranged that sections can be cut out by means of oil switches on poles, so that in no case would it be necessary to deprive a large number of customers of current. This system has proven very satisfactory, as it is comparatively seldom that the current is cut off, and an explanation of the danger incurred by the linemen is generally satisfactory to any user of current who makes complaint. It is customary to do such work at a time when it will least interfere with the larger number of users of current, and only after notifying them, and considering their suggestions as to time.

The alternative, i. e., to carry current at all times may result in serious and generally fatal accidents, a number of which have occurred in the city where the writer is employed, through lack of observance of above suggestion. And the liability in such instances would more than offset the objection to an occasional deprivation of current.

RECENT EXAMPLES OF APPLIED CHEMISTRY*

By JAMES M. CAMP

Electrochemistry embraces many and varied industries and so rapid is the progress made in this branch of science, that almost daily new processes are introduced and present ones are improved and made more highly efficient.

Of the existing electrochemical industries, the greatest is copper refining, the electrolytic copper produced during 1903 being estimated at 318 000 tons, of which the United States produced 86 per cent.

The second in importance is probably the production of aluminum, the production for 1903 being approximately 7 500-000 pounds. Both of these industries have been successfully carried on for a number of years and are now firmly established.

Numerous processes have been brought forward for the manufacture of caustic soda and bleaching powder by the electrolysis of common salt. The two processes of greatest importance are the Castner-Kellner and the Acker, both of which are in use at Niagara Falls.

The Castner-Kellner apparatus consists of a slate tank divided by a slab or diaphragm of slate, which does not touch the bottom, but dips into a layer of mercury covering the bottom of the tank. The first compartment has a carbon anode, or positive pole, and is filled with brine, the mercury at the bottom forming the cathode. The second compartment is supplied with an iron cathode, the mercury here serving as the anode and is filled with pure water, which is drawn off and replenished when in the course of operation it becomes impregnated with cautic soda. Sodium from the brine in the first compartment forms an amalgam with the mercury. A circulation of mercury between the compartments is effected by an eccentric device attached to the tank, which regularly raises and lowers one end slightly. Once in the second compartment, the sodium of the amalgam combines with the water to form caustic soda and hydrogen, the latter appearing at the iron cathode. The product obtained contains 97 to 99 per cent. of caustic, less than one per cent. of salt, and traces of sodium carbonate, sulphate and silicate.

The Acker process affords an interesting comparison with the one just described. It employs a fused electrolyte instead of

*From the retiring president's address before the Engineers' Society of Western Pennsylvania, 1905.

an aqueous solution, and, therefore, requires for its operation a much higher temperature (850 degrees C.), while the Castner-Kellner operates at 40 degrees C. Molten lead is employed instead of mercury, and the resulting lead-sodium alloy is brought in contact with a jet of steam instead of cold water.

Most of the sodium produced to-day is by this process, which consists in the electrolysis of fused caustic soda. The metal, on account of its lightness, rises and floats on the surface of the electrolyte, whence it can be dipped off by means of perforated ladles.

To-day, the most important use of sodium is in the manufacture of alkaline cyanides employed in gold extraction. It is also largely employed in the form of sodium peroxide for bleaching purposes, in the manufacture of certain aniline colors and in electroplating.

During the past two years, considerable attention has been given to the development and improvement of the methods for the electrolytic production of metallic calcium and the problem, which for a long time resisted all attempts, has at last been solved.

The product will find its greatest application in organic chemistry, where the need has long been felt for a cheap metal with reducing properties stronger than those of aluminum and magnesium and weaker than metallic sodium or potassium. The discovery should be of interest to the steel industry, replacing aluminum to remove the last traces of oxides from the molten steel, and it is only within the past month that the writer had a sample of aluminum-calcium alloy sent him for analysis. This should have wonderful reducing properties, making it much more desirable than aluminum alone.

Fifteen years ago the name of carborundum was unknown. To-day it has practically supplanted many other forms of abrasives. The inventor, E. J. Acheson, while conducting investigations regarding the production of aluminum, made some crystals of such intense hardness that he thought of their use as an abrasive, though he attempted no further development at that time. Later he undertook a more thorough investigation of the matter and, after some preliminary and highly successful experiments, he began, on a small scale, the manufacture of the substance, to which he gave the name of carborundum.

It had been noticed that in the case of overheating of the carborundum furnaces, some of the crystals next to the heating

core and which were subjected to the highest temperature, were entirely converted into graphite. This suggested the method which, as now carried on, results in the production of pure graphite, having only a fraction of one per cent. ash.

The principal form of product is rods for electrodes, the raw material employed being petroleum coke. Graphitization of anthracite coal has also been accomplished, yielding a form of graphite valuable as a lubricant. Pure artificial corundum is also manufactured commercially by the fusion of bauxite in an electric furnace, and but a little more than a month ago a patent for a new type of furnace for the production of artificial corundum was issued.

Another extensive use of the electric furnace is in the manufacture of calcium carbide. This, through contact with water, gives off acetylene gas, and the rapid development of acetylene gas lighting is largely due to the growth of the calcium carbide industry. Though a very simple synthetic process, there are many details which demand careful attention if the operation is to be successful commercially. The carbide is produced by heating together in the electric furnace a mixture of 65 per cent. lime with 35 per cent. carbon or coke.

In two departments of iron and steel metallurgy, the electric furnace has been commercially successful. In the manufacture of ferro-alloys, such as ferro-silicon, ferro-chromium, ferro-molybdenum, ferro-titanium, etc., it seems specially adapted to the required work by reason of the high temperature obtainable, while in the manufacture of special steels, its value lies in ease of control and the possibility of preventing impurities in the finished product.

Some of the most highly interesting of electrochemical investigations have been directed towards the fixation of atmospheric nitrogen. Vegetation of all kinds is dependent on nitrogenous food in the form of fixed nitrates. The natural source of supply is that formed by the decomposition of animal and vegetable matter, but under the conditions of modern civilization, this is rarely returned to the land but is burned or ultimately finds its way to the sea from which there is no return.

In view of this waste and the rapid failure of native nitrogen in the soil, we must resort to artificial fertilizers. These are obtained principally from nitrate deposits in Chili, from guano, certain rock deposits in the southern states and the new nitrate beds

recently opened up in southern California. But all these supplies are limited and it has been estimated that in a quarter of a century, twelve million tons (12 000 000) of fixed nitrates will be necessary for the production of the world's supply of wheat.

The formation of nitrous vapors by the passage of electric discharges in the air is a phenomenon noted before the end of the eighteenth century in experiments by Priestly and by Cavendish, but the establishment of a scientific principle and its industrial application are usually widely separated, and it was not until quite recently that the fixation of atmospheric nitrogen assumed an important aspect.

In 1903, two German chemists described an experimental process for the production of nitric oxide by the combustion of atmospheric nitrogen in an electric flame.

In the United States, a process has been successfully established at Niagara Falls by C. S. Bradley and D. R. Lovejoy. The system has developed into the use of a large number of arcs operating in a closed air chamber through which a definite and carefully regulated volume of dry air is passed. This air, after being subjected to the effects of the arc, leaves the apparatus carrying nitric oxides and peroxides, from which nitrous and nitric acids are produced in a sprinkling tower.

George T. Moore says of the process: "With a power sufficiently cheap and with perfect machinery, there seems good reason to believe that in the near future it will be possible to place upon the market a manufactured nitrate of soda or nitrate of potash that will be superior in quality to the deposits found in South America, and that will also be reasonable enough in price to compete with the natural product."

A few words regarding the production of electrolytic iron. The difficulty encountered in accomplishing the deposition of iron has prevented any great attention being paid to the industrial development of this process. However, recent research at the laboratory of applied electrochemistry of the University of Wisconsin has established the fact that electrolytic iron can be produced at such economy as to assure its commercial importance. The principal advantage of the process lies in the purity of the product obtained, as it is claimed that the resulting iron is 99.9 per cent. pure.

READING ERROR OF INDICATING INSTRUMENTS

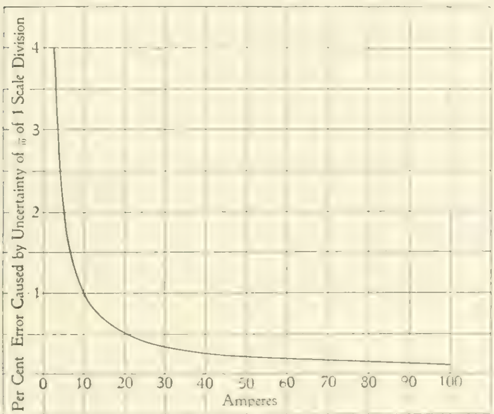
B. B. BRACKETT, Ph. D.,
Clarkson School of Technology

THE article in the August number of the JOURNAL on "Accuracy in Handling Instruments" should have made at least some reference to the probable errors in reading the actual indications of all deflecting instruments. Even uniform scale instruments cannot be used accurately for readings that are very low relative to their total range. But just how or in what way the reliability of such instruments diminishes as the deflections decrease is not understood by many electrical workers.

First, it may be observed that the controlling and the deflecting moments, without any question as to how either is produced, are both relatively weak for small deflections, and hence the friction of the pivot, however small it may be, has more effect upon the position actually assumed by the index.

Second, the reading of the position of the index may and probably does contain a small error, whatever the accuracy of the observer. In fact, if the readings are recorded to one-tenth of the smallest division of the scale, a record of say 69.7 means no more and no less than that the index stood somewhere between 69.65 and 69.75. Thus granting that the index stands exactly where it should stand, or that the instrument is perfectly accurate and is used in the most correct manner, yet the reading of the most reliable person may be in error by one-tenth of one division. That such an uncertainty exists in the value given to a reading is generally understood, and that the percentage of error due to it is greater for small readings is also recognized. But, simply through lack of proper consideration, it is generally thought that the error stands in exactly inverse proportion to the magnitude of the deflection. Since, however, the percentage of possible error depends upon the reciprocal of the deflection, the product of the possible error and the deflection must be a constant; and hence, when plotted to rectangular coördinates, these two quantities will give the familiar equilateral hyperbola having its asymptotes for axes. Here either coördinate increases more rapidly than the other decreases whenever the decreasing coördinate is small, and this condition becomes very marked for very small values of the decreasing quantity.

The curve here shown illustrates this. The instrument considered is a uniform scale, direct reading ameter, range 0-100 amperes. Since the smallest of the scale divisions represents one ampere, the reading of the position of its pointer can be made to the accuracy of one-tenth of one ampere, without any consideration of the size of the reading. This uncertainty of one-tenth of one ampere is only one-tenth of one per cent when the current read is 100 amperes, but it becomes one per cent when the instrument is used to measure ten amperes, and for currents less than ten amperes the uncertainty or the possible error in the reading of the instrument, even when its indications are absolutely correct, increases in a most remarkable way.



If the instrument in question had a longer pointer, or if its indications were read from a mirror by means of a telescope and scale, the point where only one per cent. of uncertainty enters into the readings would be reached at a smaller amperage, as would all other corresponding points of uncertainty, but in every other way the same conditions and relations would exist.

When a direct reading instrument has a scale that is more open at its middle with smaller divisions at the ends, the uncertainty of low readings is necessarily greater and the point where reasonable accuracy may be secured is not reached until the quantities measured are relatively much larger. Moreover, the reading accuracy for such instruments usually diminishes for the last one-third or one-fourth of the range of the instrument. Hence, its reading error curve would differ from the one shown both by rising more rapidly when the readings become small and by again rising for readings toward the maximum range of the instrument. In the use of any indicating instrument, the reading error for all parts of the scale should be accurately known; and if it is not understood for any particular type, the curve should be plotted and thoroughly fixed in mind.

There are two very practical reasons why the person using an instrument should understand the limits of accuracy in reading it, as thoroughly as he understands its other liabilities to error.

First, no precautions need be observed or corrections made when they deal with errors that are less than the probable reading errors.

Second, while it is in itself desirable to use instruments of such ranges that the readings are all well up on their scales, yet there are many cases where low reading voltmeters with their low resistances and low reading ammeters with their high resistances will introduce important errors caused by the changed conditions resulting from their introduction into the connections. Questions are thus continually arising as to whether the error inherent in a low range instrument, plus its small reading error, will be greater or less than the larger reading error of a higher range instrument having all of its other errors of negligible magnitude. Only a definite acquaintance with the reading error curves for the instruments that may be used will enable one to decide which instruments should be selected for any specific test.

COMMENT BY AUTHOR OF ORIGINAL ARTICLE.

The points brought out in Dr. Brackett's article, in this issue, are important and well presented. Realizing that there is a variable error at different parts of the scale, a statement of accuracy is given with all Westinghouse indicating instruments, which is different from that of other manufacturers. As an example, the certificate for precision wattmeters gives,—Maximum error $= \frac{0.4D + 0.1d}{d}$ per cent, where D= total divisions on the scale and d= observed reading.

This gives a very fair approximation. Similar formulæ are used with all Westinghouse precision meters, as they all have either uniform or logarithmic scales.

It is not well to become discouraged with an instrument and allow unnecessary errors to creep in unmolested. When the highest possible accuracy is desired, even though there are inherent errors in the instrument used, there is no harm in correcting for such as are of known amount.

Errors have a pernicious way of adding instead of neutralizing each other, and it is better to estimate the effect of such as cannot be determined than lump them all and guess at the average.

H. B. Taylor

EDITORIAL COMMENT

Alternating Current Electrolysis?

Mr. Kintner's article on "Alternating-Current Electrolysis" which appears in this issue is of particular value just now when success has attended the efforts of the engineer to apply alternating current to the electric traction problem. This matter of electrolysis is admittedly one of the most serious that the operators of the direct-current traction system are confronted with; first, because of difficulty in applying any remedy in the universally used rail return system and second, because of the insidious character of the evil, immense damage may be done before it is realized that any remedy is needed. As long as the rail is used in traction systems as the return conductor there is certain to be more or less of its current straying off and returning by other paths. It is this straying current that becomes the source of danger.

In many cases the immediate evils which would result from electrolysis are avoided by interconnecting the system of underground pipes or the sheathing of lead cable to the return circuit so that the current will return by metallic connection without electrolytic deterioration. This method, although simple, is often in practice difficult to carry out effectively, especially in large systems which may be fed from different stations. In such cases the flow of the return current and the distribution of earth potential is subject to erratic variations due to the shifting location of the load and the change in the relative load on different stations. Also it should be noted that connections which are made between the normal return system and any other conducting system with a view of protecting the latter must necessarily increase the volume of the straying currents because this action necessarily decreases the resistance of the circuit through which these currents flow. When currents pass through the earth electrolysis occurs some where; at rails or pipes or both. The connection usually made may avoid electrolysis at the pipes, but it increases that at the rail as the current is increased.

Evidently there are two ways of preventing electrolysis:

First. By keeping all current out of the ground, which with the rail return system is impossible, or.

Second. By making the currents that flow in the ground innocuous. The tests by Mr. Kintner indicate that a ready method of accomplishing this result is to make the currents alternating.

P. M. LINCOLN

Power Transmission Data

The value of a national engineering society to the progress of the profession is strikingly illustrated in a 450 page book entitled, "High Tension Power Transmission," which is a reprint of papers and discussions from the Proceedings of the American Institute of Electrical Engineers. This book is the outcome of a High Tension Transmission Committee continuing from 1902 to 1904, of which Mr. Mershon was chairman and Messrs. Blackwell, Chesney, Lincoln, Cory and Hunt were members.

The problem of high tension transmission is an engineering problem. In one sense the elements which enter into it are simple, but the problem is difficult and comprehensive. It is not one which can be solved by a single man or by some particular scheme. Speaking generally, no two power plants are alike. Differences in conditions as to sources of power, topography, climate, distance, amount of power and the requirements as to its distribution and application for commercial uses, are all elements which enter into the general problem. The problem is therefore one for the engineering profession as a whole. Engineers who operate plants and who use apparatus, as well as those who invent and design, must contribute to its solution and it is a problem which does not admit of final solution. It is a continuous problem for it is one of engineering evolution.

One can scarcely imagine a department of engineering work in which interchange of experience and ideas and discussion of methods is of more importance than in high tension work, where experience is so large a factor and where development is so rapid.

Through its Transmission Committee the American Institute of Electrical Engineers has brought together a unique collection of engineering ideas and experience. It has brought together engineers from rival manufacturing companies and consulting engineers, and it is difficult to suggest an important transmission company in America whose engineers have not contributed to this collection of papers and discussions. The book contains some 25 short

papers which are the basis of discussion. The index of contributors includes over one hundred names.

A large proportion of the book is devoted to matters which have become important and to experience which has been acquired within the last five years. On the other hand, it is not unlikely that the book will in many respects be quite out of date five years hence. The advance which will be accomplished in the future will owe a great deal to this substantial contribution to engineering progress. Such work is one of the most valuable accomplishments of a national engineering society.

CHAS. F. SCOTT

Observation Errors

The article on "Reading Error of Indicating Instruments," by Dr. B. B. Brackett, in this issue of the JOURNAL, brings out some important precautions to use in connection with the use of measuring instruments. It is well to bear in mind, however, that there may be other and more serious causes of error introduced.

When an extended series of observations is being taken, such as running a curve of the performance of some piece of apparatus, the actual error due to observation will practically be cancelled. There are other sources of error, however, which may produce considerable variations in the result obtained. These errors may be divided into two classes; the first class, those which produce a constant percentage error, such as error in calibration, temperature errors, effects of frequency in alternating-current instruments and thermal effects in direct-current instruments. In the second class may be placed errors which change in magnitude with varying deflections, such as errors of observation, lost motion in moveable parts of instruments, incorrect zero setting and like causes.

In estimating the accuracy with which any readings have been taken, it is necessary that these different errors be considered separately and means taken to eliminate them as far as possible. Errors in calibration, of course, are beyond the control of the observer. Errors of observation may be eliminated by taking a considerable number of readings, it being safe to assume that an average will be practically correct so far as the actual indications of the instrument are concerned.

The other errors are of importance in estimating the accu-

racy, as by a knowledge of the characteristics of the particular instrument it may be possible to reduce these to the very smallest quantity, while these same instruments if improperly used may show grave discrepancies.

As stated in Mr. Taylor's note, the possible accuracy obtainable with the Westinghouse precision instruments is given as dependent upon two sources of error; one of these, representing a fixed deflection, is intended to cover changes due to faulty leveling or balance of instruments, incorrect zero setting and possible errors of observation. It is assumed, however, that a sufficient number of readings will be taken to eliminate this latter error.

The other, the fixed percentage error, is intended to cover errors in calibration, effects of frequency, temperature, etc.

F. Conrad

Mr. Buck's Point of View

The point of view of an engineer whose position has advanced from $4.50 per week to that of electrical engineer of one of the foremost power companies in the world in the short interval of ten years is well worth considering. His estimate of the relative value of the different elements in his early training is apt to be a pretty accurate measure of their value to others.

The statement is made in a recently published article that the entrance examinations at one leading university are for the purpose of determining how well the student has done his work in the preparatory school, while in another institution the purpose is to determine the ability of the applicant for doing university work. Obviously Mr. Buck's view, as expressed in his article on a preceding page, is that at the time of graduation the class rank and the grades which have been secured for work done are of far less consequence than the preparedness for the engineering or other work which is to follow. His emphasis upon the value of a scientific and technical education, whether a man is to be an engineer or not, might have been a rather startling proposition several years ago, but its soundness is coming to be generally recognized.

ALL STEEL CARS ON THE LONG ISLAND RAILROAD

A large number of these cars have been ordered by the Long Island Railroad. Over 130 have already been built. These cars are all equipped with the Westinghouse pneumatic multiple-unit system of control. Each motor car has two motors mounted on the same truck, one on each axle. The truck at the other end of the car has no motors. The motor cars weigh 83 000 pounds each and are capable of maintaining a maximum speed of 55 miles per hour and a schedule speed of 25 miles per hour including stops, 1.6 miles apart.

The trains accelerate very smoothly and evenly, and are brought to a stop in the same even manner by the use of an especially designed air brake controlled by the new Westinghouse graduated release triple valve. In this respect the equipment is a great improvement over any electric train hitherto put in service. The car bodies are being furnished by the American Car Company of St. Louis and the trucks by the Baldwin Locomotive Works.

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THE TRANSMISSION CIRCUIT*

AN ELEMENTARY CONSIDERATION OF SELF-INDUCTION, REGULATION AND MUTUAL INDUCTION

CHAS. F. SCOTT

THE alternating current when first introduced for lighting presented many new problems to the electrical engineer. Numerous difficulties and dangers were predicted by the theorist, but in ordinary service most of these have fortunately lain dormant. These difficulties are apt to appear, however, when alternating current work is attempted on a large scale. The introduction of large units, heavier currents, higher potentials or power service is apt to increase the effects of self-induction and capacity, so that they now demand careful consideration. The impetus that electrical engineering is receiving from the introduction of the polyphase system, which brings with it large units and long distances, naturally directs attention to the general problem of alternating current transmission and distribution.

A complete and exhaustive solution of this problem is by no means a simple one, and the attempted solutions generally lead to formulæ and diagrams which are possibly even more perplexing than the phenomena. If even the electrician who devotes all his energy to new problems can scarcely keep abreast of the times, it is not surprising that the practical engineer and station manager becomes perplexed and confounded at the apparently erratic phenomena observed in practice or described in print. Many theoretical articles, although evidently intended to be of service in engineering, show apparently no adequate appreciation of the practical bearing and relation of the subjects treated. Conse-

*This article is the first of several to appear in the JOURNAL treating generally of induction and capacity in electric circuits. Some of these articles will be reprints of papers which are not conveniently accessible; others will be new. The present article is an extract from a paper read before The National Electric Light Association, March 1st, 1894. See editorial comment.

quently, the average engineer becomes bewildered and perplexed, and concludes that theoretical explanations are of little value to the practical man. There are, however, many problems of great practical importance which admit of fairly simple statement and explanation.

The particular element to be considered in the present paper is the transmission circuit.

EXPERIMENTS ILLUSTRATING SELF-INDUCTION

One of the fundamental characteristics of alternating-current work is self-induction. The effect of self-induction is most readily

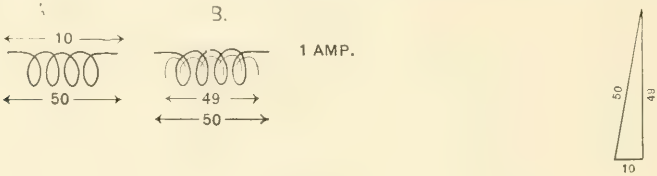


FIG. 1

shown by a simple experiment. A wire having a resistance of 10 ohms may be wound in a coil. Ten volts will send a continuous current of one ampere through this coil. An alternating current of a certain frequency will require 50 volts for forcing one ampere through the same wire (Fig. 1A). (In the diagrams the numbers

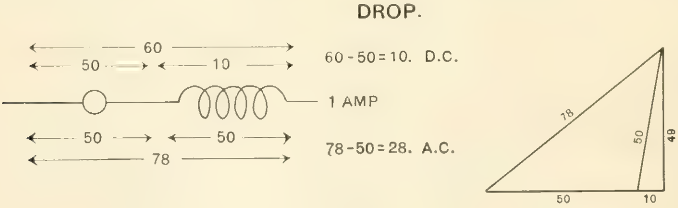


FIG. 2*

above the circuit are for continuous current and those below are for alternating current.) If a 1-ampere, 50-volt lamp be placed in series with the coil and a current of one ampere be passed through the two in series, the e. m. f. required for continuous current is 10 volts on the coil and 50 volts on the lamp, or 60 volts across the circuit, and the e. m. f. required for alternating current is 50 volts across the coil and 50 volts across the lamp, which gives, not 100

*In the diagrams in this article D.C. is used for direct current and A.C. for alternating current.

volts, but 78 volts measured across the two in series (Fig. 2). If two lamps be placed in multiple and connected in series with the coil, two amperes will require for continuous current 20 volts on the coil and 50 volts on the lamps, or 70 volts across the circuit. For alternating current the e. m. f. on the coil is 100 volts and on the lamps 50 volts, and on the circuit across the two in series the e. m. f. is 120 volts (Fig. 3).

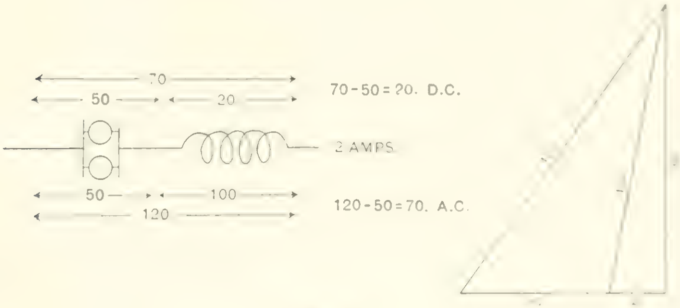


FIG. 3

The two lamps which are in multiple may be placed in series with a small coil. This small coil may be so proportioned in its number of turns and resistance that an e. m. f. of 50 volts will send one ampere alternating current through the combination

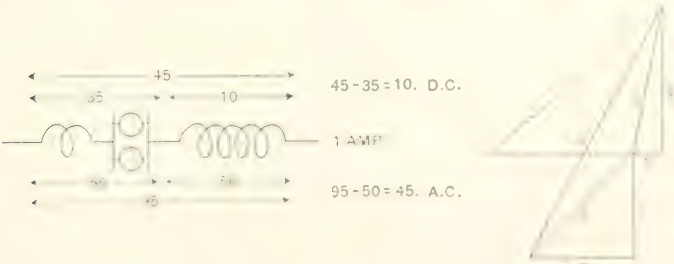


FIG. 4

(i. e., the small coil and the lamps), and a continuous current of one ampere would be caused by 35 volts. This combination may be treated as a unit and may be used to replace the single lamp in the above test (Fig. 2). If this combination be placed in series with the first coil (the one used in the first experiment) the e. m. f. required for sending the continuous current through the circuit will be 10 volts on the coil and 45 volts on the circuit.

If the alternating current of one ampere be sent through the circuit, 50 volts will be required across the combination and 50 volts across the coil, the same as with the single lamp, but the e. m. f. across the circuit is no longer 78 volts, but has increased to 95 volts (Fig. 4).

The important facts to be noted in these experiments are: (1) That the sum of the alternating e. m. fs. on the elements connected in series is greater than the e. m. f. required upon the terminals of the circuit; (2) that the alternating e. m. f. for supplying the lamps in series with a coil is greater than the continuous e. m. f., and (3) that the difference between the two becomes greater as the number of lamps is increased (Figs. 2 and 3). It is also to be noted (4) that if the same alternating current be supplied through a coil, first to a lamp alone and then to a combination including lamps and a coil, a higher e. m. f. is required when the combination is used (Figs. 2 and 4).

These relations, which seem rather perplexing, may be illustrated in a very simple way by diagrams. In the case of the coil alone, in which 50 volts are required for producing one ampere alternating current and 10 volts for one ampere continuous current, these two e. m. fs. may be represented by the hypotenuse and one side of the familiar right angle triangle. The remaining side represents the counter e. m. f. in the coil. If a second wire had been wound in this coil in parallel with the first, it would be found that when one ampere is passing there is an e. m. f. on the terminals of the second, or idle wire, of 49 volts (Fig. 1B). This e. m. f. is caused by the field produced by the alternating current. An equal e. m. f. is, of course, induced in the wire carrying the current, as the two wires occupy virtually the same position. This counter e. m. f. is seen to correspond with the third side of the triangle. Suitable measurements would show that this counter e. m. f. is not coincident with the current through the coil, but that its maximum value occurs when the current is passing through its zero. This relation is shown in the diagram by the 90-degree relation of the lines representing counter e. m. f. and the volts required for sending continuous current through the line. Triangular diagrams are also given in connection with a number of other figures. The relation between the lines in the triangle and the voltages in the figures showing the coils and lamps can be readily seen, as the numbers denoting the voltages are given in both cases.

SELF-INDUCTION IN CIRCUITS

An ordinary circuit may be considered as a choke coil in which there is a single turn. The action in this case is very similar to that illustrated above with a coil of many turns. The effect of self-induction in a circuit may be most readily understood by some simple diagrams. A current of say five amperes is delivered at 100 volts over a circuit of one-fifth of an ohm resistance. The self-induction of the circuit is such that five amperes generate a counter e. m. f. of 10 volts. Both continuous and alternating currents are used, and the generator e. m. f. is in each case adjusted to give 100 volts at the load.

The load consists, first, of five incandescent lamps. A coil of high self-induction is then added, which increases the current from five to five and one-tenth amperes. One of the lamps is then cut out and replaced by coils of such a self-induction as to give a total of five amperes. Then all of the lamps are cut out and coils substituted of such a number as to take five amperes at 100 volts. The e. m. f. required on the generator and the resulting drop, or difference of e. m. f., at the dynamo and at the load are given in the diagrams and in the following table:

	Continuous Current	Alternating Current			
	Fig. 5.	Fig. 6.	Fig. 7.	Fig. 8.	Fig. 9.
Current in line..........	5	5	5.1	5	5
Current in lamps........	5	5	5	4	0
Current in coils.........	0	0	1	3	5
E. m. f. on load.........	100	100	100	100	100
E. m. f. on line.........	1	10	10	10	10
E. m. f. on generator....	101	101.5	102.5	106	110
Drop, total..............	1	1.5	2.5	[illegible]	[illegible]

It is to be noted that with exactly the same circuit for supplying five lamps with the same amperes at the same e. m. f. there is an increase of drop between generator and load when continuous current is replaced by alternating current. This drop is much less than the volts required for sending the alternating current through the line, and it, moreover, increases enormously as the load becomes even slightly inductive. Thus, when the current is increased only two per cent. (from five to five and one-tenth amperes, Figs. 6 and 7) by the addition of inductive load to the lamp load, the increase of drop due to self-induction is increased from one-half per cent. to one and one-half per cent., or an increase of three-fold. When the load consists of four lamps and coils are added in multiple to take a total of five

amperes from the generator, or the same as that taken by the five lamps, the drop is four times the drop when five lamps alone are in circuit. If the remaining four lamps be replaced by coils, the drop does not increase in proportion, but from six to only 10 per cent. The effect, therefore, of a slight self-induction in the load causes a much greater proportional drop than the presence of a large self-induction. A counter e. m. f. of 10 per cent. is not at all likely to occur in a 100-volt line carrying a small current. The figures given, however, serve as an illustration of the percentage variations which are possible in other parts of the system.

DROP IN CONTINUOUS AND ALTERNATING CIRCUITS

The word "drop" in continuous current calculations has a perfectly well defined meaning. In the case of the five lamps which take five amperes at 100 volts through a circuit of one-fifth of an ohm, as illustrated in Fig. 5, the drop is: (1) the difference between the e. m. f. at the generator and at the lamps, or one volt, which is one per cent.; (2) it is the e. m. f. required for sending the current through the line; this is equal to the current multiplied by the resistance, and is the e. m. f. which would be required for sending the current through the line if the load be short circuited; (3) a drop of one per cent. means also that the energy lost in the line is one per cent. of that delivered by the generator; (4) a loss of one per cent. in the line also signifies that the energy delivered is one per cent. less than that supplied by the generator.

In alternating current work the same uniformity does not exist; for example, in the experiments with the same five lamps and the same line: (1) the generator pressure was 101.5 volts, or one and one-half per cent. higher than that of the lamps; (2) the e. m. f. required for sending a current through the line short circuited is 10 volts, or 10 per cent.; (3) the energy lost in wires is $C^2 R$, or five watts, which is one per cent. of the energy when five lamps are supplied. If four lamps and low resistance coils are connected to the circuit, the energy delivered is, say, 400 watts and the loss is one and one-fourth per cent.; (4) if the coils alone are supplied and their combined resistance is equal to that of the circuit, or one-fifth of an ohm, then the losses in load and line are equal and the actual line loss is 50 per cent. The apparent energy at the generator is 550 watts (110 volts and five

amperes) and the apparent energy delivered is 500 watts (100 volts and five amperes), so that the apparent loss is nine per cent.

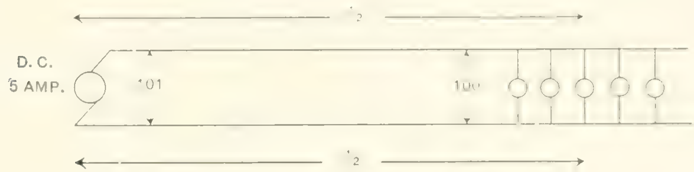


FIG. 5—DROP = 101—100 = 1

FIG. 6—DROP = 101.5—100 = 1.5

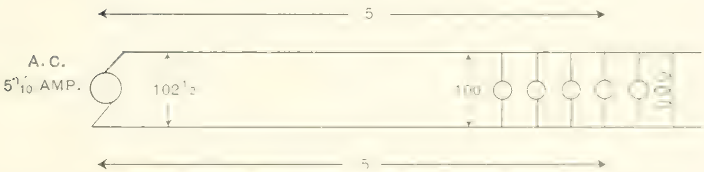


FIG. 7—DROP = 102.5—100 = 2.5

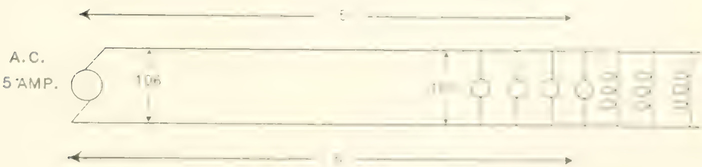


FIG. 8—DROP = 106—100 = 6

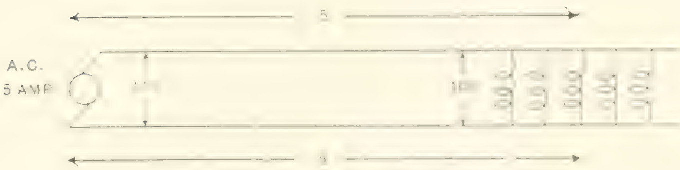


FIG. 9—DROP = 110—100 = 10

It is, therefore, evident that the several elements commonly referred to as drop or per cent. loss with continuous current are

so modified when alternating current is used that it is possible for no two of them to have the same value. Moreover, with alternating current, none of these elements may have the same per cent. value as that for continuous current on the same circuit.

LOSS AND REGULATION

The two vital factors in the line are loss and regulation. The losses are $C^2 R$, and should be expressed in watts or horsepower, or as a per cent. of the energy delivered to the line. The practical point in regulation is the difference in e. m. f. at the generator and at the load. When these two factors are known, it is generally immaterial what e. m. f. might be required for

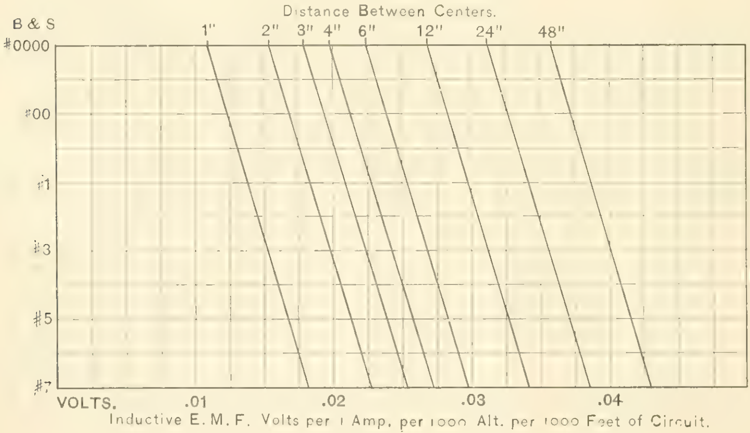


FIG. 10

sending current through a short-circuited line. The word "drop" is applied to the difference in e. m. f. between the generator and the load. The regulation is generally expressed in per cent. of generator e. m. f., but in this paper the e. m. f. at the load will be considered 100 per cent., as this is the element to be kept constant while the e. m. f. of the generator is variable, depending upon the load and other elements.

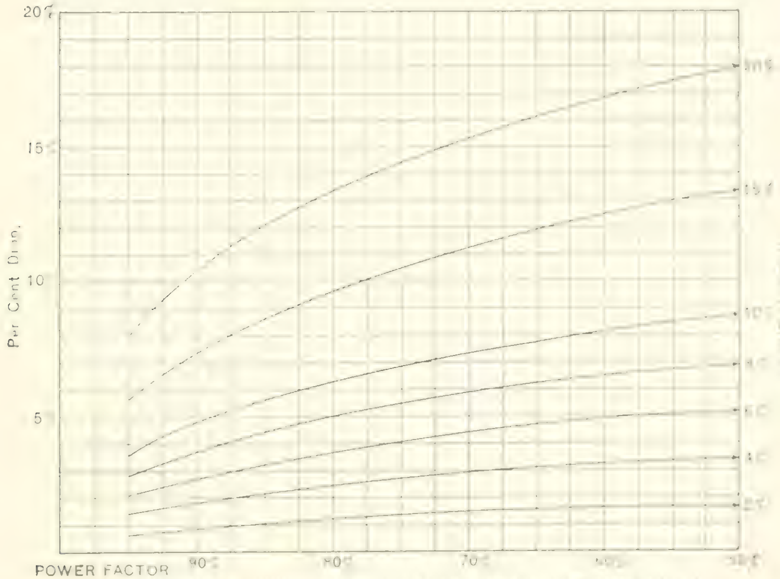
COUNTER E. M. F. IN ALTERNATING CIRCUITS

Regulation in a circuit is in general determined by three elements—the resistance, the counter e. m. f. of the circuit and the power-factor of the load. The counter e. m. f. of the line depends upon the size of wire and the distance between wires, and it increases directly as the length of the circuit, the current and

the alternations. The counter, or inductive, e. m. f. of a line has been calculated for a number of cases, which are likely to occur in practice, and the results are given in Fig. 10.

DROP IN ALTERNATING CIRCUITS

The drop, or difference of potential between generator terminals and the load terminals, due to the counter e. m. f. of the line, depends, as has been shown, upon the self-induction of the load. The latter is best expressed by a power-factor, or a factor by



Inductive Drop for Different Inductive E.M.F.'s and Power Factors of Load.

FIG. 11

which the product of the amperes and volts, or the apparent energy, must be multiplied to give the true power in watts. The power-factor for incandescent lamps is 1.00, as the apparent energy is equal to the true energy. The power factor for transformers loaded with incandescent lamps is usually over .99. The factor for unloaded transformers varies from .50 to .80, and in open magnetic circuit transformers, notably the "hedgehog," the factor may be as low as .05. The drop due to self-induction on the line (which, plus the ohmic drop, will give approximately the total drop), corresponding to various power factors of the load, is given in Figs. 11 and 13. The curves show that if the

power-factor be 100 per cent., as it is with incandescent lamps, the inductive drops for various counter or inductive e. m. f.'s are .02 per cent. for two per cent.; .08 per cent. for four per cent.; .18 per cent. for six per cent.; .32 per cent. for eight per cent.; .5 per cent. for 10 per cent.; 1.2 per cent. for 15 per cent., and 2 per cent. for 20 per cent. The curves show that the drop increases very rapidly at first if the power-factor becomes less. These relations may be elegantly determined by a simple diagram on section paper ruled in tenths. Draw an arc through a quadrant with a radius of 100. Graduate the horizontal and the vertical scales, beginning with 0 at the center and reaching 100 at the circle. On the horizontal scale find the point corresponding to the power-factor of the load, follow up the vertical line to the circle. This line represents the counter e. m. f. of the load and its length read on the vertical scale gives the counter e. m. f. of the load in per cent. of the e. m. f. on the terminals of the load. From the intersection with the arc of the circle proceed horizontally a distance corresponding to the effect of the resistance of the line, i. e., to the e. m. f. required for sending an equal continuous current through the line resistance, expressed in per cent. of the e. m. f. upon the load. From this point proceed upward a distance equal to the counter e. m. f. of the line expressed in per cent. of the e. m. f. on the load.

A line from the center to the upper end of this vertical represents, in direction and magnitude, the e. m. f. which must be impressed on the circuit. If from the same center an arc be drawn through this point to the base, the scale divisions on the base between the two arcs measure the total drop caused by the line, in terms of the e. m. f. at the load. This construction is shown in Fig. 12 for two cases. The e. m. f. corresponding to the effect of the resistance of the line, or the "resistance volts," is two per cent. in each case and the counter e. m. f., or the "reactance volts," is taken as 10 per cent. in each case. In one example the power-factor is taken as 100 per cent., and in the other case as 0.8 or 80 per cent. The total drop in the first case is seen to be a trifle over two per cent. and in the second case about eight per cent.

SELF-INDUCTION IN TRANSFORMERS, ETC.

Self-induction exists in line, generators, transformers, secondary wiring, and sometimes in the load. In each case the

effect of the self-induction upon regulation depends largely upon the self-induction of the total load which it supplies. Thus, the regulation of a generator depends upon the total self-induction of the line, transformers and load. Again, the regulation of line supplying transformers depends upon the self-induction of the transformers, as well as that of the useful load. The same

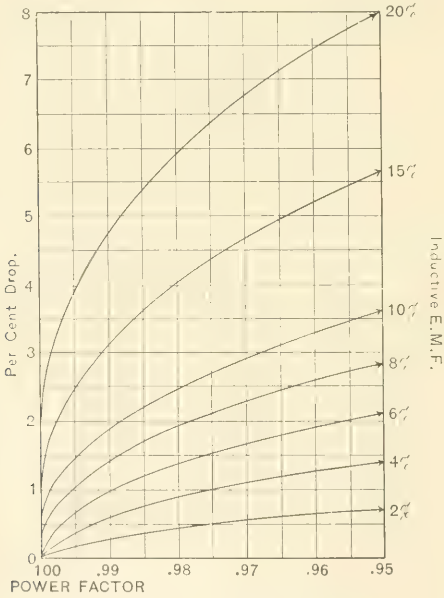
Drop in Inductive Circuits.

FIG. 12

analysis and diagrams which have been used above in connection with the line will apply to the transformers and approximately to the regulation of the generator.

An ordinary transformer has a primary self-induction and a secondary self-induction and a mutual induction, which become a ready source of a very complicated and perplexing analysis when the complete action is described in theoretical terms.

Practically, however, the action of the self-induction in the transformer may be expressed in a very simple way, and it is readily seen that this self-induction has a very important bearing upon the regulation of the transformer. The regulation of the transformer is very similar to that of a line, as explained above. If the secondary coil be short-circuited, the e. m. f. on the primary may be adjusted so that the normal full-load current passes through the apparatus. This e. m. f. is analogous to the e. m. f. required for sending current through a short-circuited line, and



Inductive Drop for Different Inductive E.M.F's and Power Factors of Load.

FIG. 13

in ordinary transformers is practically equal to the counter e. m. f. of self-induction, and may be considered equal to it.

A transformer may be taken for experiment in which the e. m. f.'s are 1 000 volts and 100 volts. If five volts, or one-half per cent., is required for sending through the primary a continuous current equal to the normal full-load current of the transformer, and if a similar e. m. f. in the secondary is one-half a volt, or one-half per cent., then the ohmic loss in the transformer is one per cent. and the drop in pressure at the

secondary terminals between no load and a full load will be one per cent. if the self-induction be negligible. If, however, there is a self-induction so that 100 volts, or 10 per cent., is required, at a given frequency, for sending an alternating current of the normal strength through the primary when the secondary is short-circuited, then the drop in pressure is in general greater than one per cent., depending principally upon the character of the load. The load may be non-inductive, as lamps, or it may be more or less inductive. The experiments described above, in which a line had the same per cent. ohmic and inductive characteristics as the transformer just described, apply to the transformer as well as to the line. The drop on such a transformer, therefore, may vary from one and one-half to 10 per cent. when delivering its rated current. Arc lamps, or fan motors, will produce a very much greater drop than incandescent lamps. The power-factor of an alternating-current arc lamp varies considerably, but in a number of cases has been found between 85 and 90 per cent. The drop, when incandescent lamps are replaced by arc lamps on the transformer just described, increases from about one and one-half to five or six per cent.

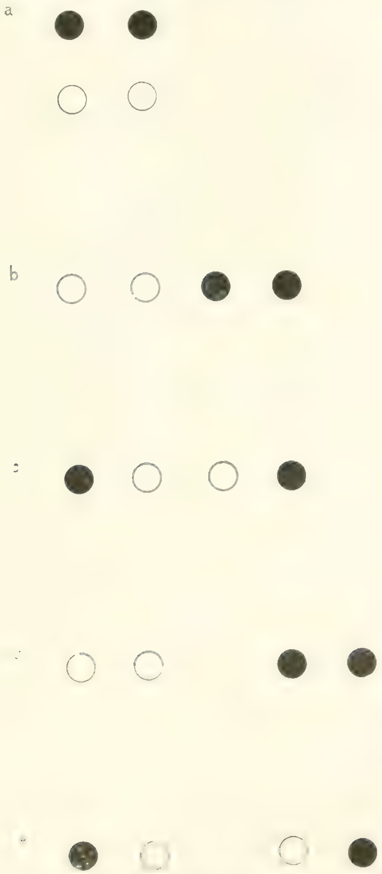
A secondary line, if it carry a large current, may have a counter e. m. f. of several volts. This may not be enough to increase appreciably the drop in the line between the transformer terminals and incandescent lamps. But the transformer, however, delivers current to the secondary circuit and to the lamps, so that the regulation of the transformer may be affected by the self-induction of the secondary circuit. Cases have occurred in which transformers of a very old type possessing high self-induction were supplying very large secondary currents and the resulting drop in the transformers was increased several per cent. For example, a circuit of No. 0000 B. & S. wire supplying 100 amperes to 50-volt lamps at a distance of 100 feet has an ohmic drop of two per cent. The constant for counter e. m. f. of this circuit, if the wires be six inches apart, is .022. The volts at 16 000 alternations are $.22 \times 100 \times .1 \times 16 = 3.52$, or seven per cent. of 50 volts. The inductive drop in the line corresponding to seven per cent. is .25 per cent. The power-factor of the aggregate service of the transformer is the second side of a right angle triangle, of which seven is one side and 100 is the hypotenuse. This is 99.7, which is the power-factor of the total load on the transformer. If the inductive e. m. f. in the transformer be 10

per cent., the inductive drop is 1.2 per cent.; if 20 per cent., the inductive drop is 3.4 per cent., and if 30 per cent., the inductive drop is seven per cent. The aggregate drop in the transformer and secondary circuit in the latter case would be, say, two per cent, for ohmic drop in transformer, two per cent. ohmic drop in line, seven per cent. inductive drop in transformer and .25 per cent. inductive drop in line, or a total of 11.25 per cent. The necessary ohmic drop is four per cent. and the inductive drop resulting from self-induction in transformer and line is therefore 7.25 per cent. If the number of alternations be reduced to 7 200, the inductive drop would be reduced from 7.25 per cent. to one and one-half per cent.

MUTUAL INDUCTION

If two circuits be run on the same pole line they act as a transformer, in which one circuit carrying current may act as a primary and induce e. m. f. in the other as a secondary. If the latter circuit is connected with the same dynamo and is delivering current, its e. m. f. will be slightly raised or slightly lowered by the effects of the first circuit. Conversely, the second circuit will have similar effect upon its neighbor, raising or lowering its pressure by a slight amount. If the two circuits be connected to different dynamos which are running at slightly different speeds, then the e. m. f. induced by one circuit upon the other will sometimes increase and at other times decrease the e. m. f. of the circuit, depending upon whether the two currents at a given moment are flowing in the same or in opposite directions. This fluctuation may cause variations in the intensity of the lights supplied. It is readily detected in the service of some central stations, and is of course most marked at time of full load, as the induction of one circuit upon another depends upon the strength of current carried. The fluctuation due to this action may be readily distinguished from that due to slipping of belts or irregularity in engine speed, as the induction effect is due to the difference in alternations between two machines, and the speeds of the two machines are apt to vary slightly from time to time, giving a gradual variation in the rate of fluctuation of the lamps. The fluctuation due to mutual induction of lines occurs only at the end of the line, and is not observed in the station, while the other causes affect the station lights also. The number of volts e. m. f. set up in one circuit by a parallel circuit depends upon the cur-

rent, the frequency, the distance which the lines are parallel and upon the relative positions of the four conductors. The distance between wires may be six inches or six feet without affecting the mutual induction, provided the relative positions be unchanged. Several dispositions of circuits are shown in the



a	[illegible] ALT.	[illegible] VOLTS.
	7 2[illegible] ALT.	[illegible] VOLTS.
	3 000 ALT.	.0067 VOLTS.
b	16 000 ALT.	.015 VOLTS.
	7 200 ALT.	.0065 VOLTS.
	3 000 ALT	0028 VOLTS.
c	16 000 ALT.	.070 VOLTS.
	7 200 ALT.	.032 VOLTS.
	3 000 ALT.	.013 VOLTS.
d	16 000 ALT.	.006 VOLTS.
	7 200 ALT.	.0027 VOLTS.
	[illegible]	[illegible]
e	[illegible]	[illegible]
	7 200 ALT.	.050 VOLTS.
	[illegible]	[illegible]

[illegible]

FIG. [illegible]

accompanying Fig. 14, and the number of volts per thousand feet which are induced in either circuit by one ampere in the other are given in connection with each figure. The number of volts required for producing objectionable flickering in the light depends upon the voltage of the lamps in service, the efficiency

at which they are run and the general surroundings in which they are placed, notably the relation of lamps to reflectors, white walls, etc., and the general disposition of the customer.

An e. m. f. of one-half per cent. induced in one circuit by another can in some cases be detected, and usually more than one or two per cent. will cause objectionable flickering.

METHODS OF REDUCING MUTUAL INDUCTION AND SELF-INDUCTION

The mutual induction is reduced by bringing the wires in each circuit close together and separating the circuits. The effect of this mutual induction may be neutralized by crossing one of the lines at its middle point, so that induction in the first half of the line is counteracted by the induction in the second half. It is readily noted that the effect of self-induction in a circuit is reduced as the wires are brought close together, or if each conductor be divided into several wires in multiple and separated. The effect of self-induction is diminished as the number of alternations is reduced. The following points are also to be noted in connection with the inductive drop: If the power-factor be nearly 100 per cent., the inductive drop increases as the square of the counter e. m. f. If the e. m. f. of the circuit be increased and the same power be delivered over the same circuit, the per cent. counter e. m. f. decreases as the square of the e. m. f. delivered, and the inductive drop decreases approximately as the fourth power. If the number of alternations be decreased, the counter e. m. f. decreases directly and the inductive drop decreases as the square. The inductive drop at 7 200 alternations is less than one-fourth of that for 16 000 alternations for ordinary power-factors.

USEFUL CO-OPERATION*

W. C. KERR

President, Westinghouse, Church, Kerr & Company

A POLITICAL editorial once began with the analogy: "There are two kinds of rubber overshoes—bad and blank bad; the former are difficult to obtain." If co-operation be reckoned by what is easily obtainable, its quality and quantity are scarcely satisfactory. This does not seem to reflect upon intent, but to a considerable degree measures limitations. The reason we find so little co-operation is that so few know what it is, fewer yet know how to use it, and opportunity is ever as elusive as a wandering purpose permits. As Mr. Dooley said of work: "If it's wurruck yure a lookin' fur thar's lots of it around here that nobody's a doin."

The present is a time at which there seems to be an unusual tendency towards co-operation. It seems more like a tendency than a definite practice. It is frequently too abstract to be effective, too variable to be relied on, too spasmodic to be useful.

Just what are we talking about? What is co-operation anyway? Aside from the common definition of "working together to one end," co-operation seems to mean what any man happens to have in mind when he uses the word. In a rudimentary way, observation would suggest that to one it means—help me make a sale, to another—give me low prices, or lend me your paw to pull my chestnuts out of the fire. Sometimes it may appear to mean—listen to me and do what I say; or what's mine is mine and what's yours is mine. Rarely is it—what can I do for you? or, how can we combine forces for the common good?

Co-operation to us should be the intelligent and loyal combination of the knowledge, skill, and strength of position acquired through years of service. Did it ever occur to you what potential strength there is in our general interests which can within itself conceive, design, and create a comprehensive property and furnish most of the chief apparatus for it? Or did you ever realize the extent to which our varied activities could be lifted to a plane high above others if the fullest advantage were taken of our opportunities possessed by no other interest or combination of interests? These

*A paper read at a meeting of the district managers of the Westinghouse Electric & Mfg. Company, November, 1905: See editorial comment.

activities cannot be elevated separately. They must rise together. Just write the word corporation several times and then see how much harder this has made it to write co-operation. Perhaps we have been too intent on our "daily grind" to perceive the latent power of the waters that flow by our mill.

No one seems to doubt the desirability of co-operation between varied interests such as are gathered under our banner. All seem to realize that it is potent for good. I have never heard of any one volunteering to set up his own practice as a guide for others in determining what co-operation is or how it can be effectively practiced.

The co-operation sphere seems to me to be a ball of many colors, slowly rotating, and while it appears to constantly show the same general form, its various sides, colors, markings, and other characteristics appear over the horizon and disappear with an ephemeral rapidity which leaves behind only an intangible impression.

Co-operation often seems to be a matter of the moment, defined by instantaneous needs, and usually regarded, with a certain accumulativeness of human instinct, as something that is coming to one rather than going from him.

From what I have seen in twenty-three years, I have a firm belief that one difficulty in obtaining true co-operation lies in the fact that we have a very imperfect idea of what we are trying to obtain. Some things are hard to define. Entomologists have tried to define the word "insect," but a very astute authority prefaced his writings by stating that he had found this so difficult that he would suggest the reader to catch a grasshopper, look at it for a while, and gain his own impressions regarding the main characteristics of an insect.

I think the best idea of co-operation will be the impression obtained by any one through experience with true co-operation, regardless of just what form it may take. The real thing is rare, though it is frequently approximated in various degrees. Instead of definition, it may be more useful to apprehend some of the basic principles which underlie it.

The first of these is corporate unselfishness; the second is administrative unselfishness; and the third is personal unselfishness. With a selfish motive, co-operation cannot exist.

The next necessity is diligence. Laziness can only co-operate negatively, by doing nothing harmful. Passiveness is seldom useful. In a matter of this kind, you can't be passive. You either co-operate

or you don't, and if you don't there is a failure at your door. All things are more or less hard to do and faithful diligence is requisite in doing those things which create the platform on which co-operation can rest.

Our interests breathe the gale of advancing and ever changing arts, with all their complexities, anomalies, and uncertainties. With us "nothing there is, can pause or stay." Thus our duty is made harder to perform than if we lived in the quiet atmosphere of conventional operations. Difficulties and their overcoming bring opportunities, and who would ask for ease at the price of stagnation. It was Tacitus who created a solitude and called it peace.

Another necessity is honesty of purpose, which involves truthfulness; not merely the willingness to tell the truth, but the ability.

There must be a strong motive of the kind that makes men successful in the world and then keeps them successful after they get there, which motive is an assemblage of virtues, of which the shortest expression is "the real thing." All pretensions, shams, subterfuges, sharp practices, equivocations, pettiness, double meanings, half answers, procrastinations, autocratic manners, and other adverse elements of human nature must be expurged from motive and practice before "the real thing" exists, and until you have the real thing and lots of it you will have no co-operation.

Co-operation is a bigger power in the world than is implied by its limited application to the affairs of our several corporate interests. Like credit, it is a fundamental principle underlying successful action in the world of peace, commerce and war. It is practiced in nature by the ants and bees, and is more or less reflected in the principles of mechanics, even to the holding together of the solar system. So if any one thinks that co-operation is a little bit of a thing which we are more or less creating or failing to create, they are taking a very limited view of its sphere.

But we need not now concern ourselves with co-operation in its fullness applied to many things. We need it only with reference to its opportunity to serve the best interests of a dozen corporations and the men in them.

The laying down of laws for co-operation is useless. We may more or less systematize the results of practice, but the laws are the laws of purpose, of motive, of integrity, of unselfishness, of willingness to assist, of diligence, faithfulness, and fidelity to trust, and I think if it is viewed in any other way we will only get the imitation of the real thing, and all imitations are bad.

There is no room for co-operation that does not co-operate, and therefore it is only useful co-operation that interests us, and useful means, good for something. It has been said that any one who gets approximate justice in the world is doing very well. It is a common remark that nothing is perfect. We all know that our neighbors and friends are imperfect, and we even sometimes suspect ourselves. The perfectionist in this world has a hard time. He is subjected to continual disappointment. If he is chiefly worried about the imperfections of others, he may regard himself with complacence until he suffers the more severe fall because of the height his conceit has attained. If we will all assume that we are quite imperfect, that we express ourselves badly, and that our judgment is liable to considerable improvement by contact with that of others, we may add something of a desirable personal attitude to the basic principles already recounted.

If then we come to co-operation in a spirit of true helpfulness we may make it real, and if it is real it may be useful.

There is little hope of the representatives of any concern co-operating with those of any other unless they have the ability to co-operate among themselves. If from the corporate management of any organization down the ranks to those in least authority, there cannot be a wholesome co-operation, free from jealousy, and with all efforts bent to one end, it is useless to ask the members of that organization to co-operate with others further removed.

Co-operation, like charity, begins at home. These virtues have several features in common, which I have not time to relate. Internal co-operation within a given organization is facilitated by success, pleasantry, mutual understanding, close acquaintance, and charity for each other's shortcomings. It cannot be ordered and the lack of it is even difficult to censure. There are so many men with so many minds that each is too much inclined to be a law unto himself. Co-operation cannot be purchased, but it can be inspired. Some one once remarked that "money will buy a pretty good dog, but it won't buy the wag of his tail." If you want internal co-operation, the way to have it is to get busy and co-operate and never miss a chance. Lean over backwards to do it. See how much you can do to help some one else, instead of how little, and if each concern within our interest will get this spirit it will get something useful and ripe for extension.

Any man conspicuously lacking in these characteristics has in him something of smallness, selfishness, even meanness, which it is

his business to get rid of, and he can get rid of it quickly, providing he possess any qualities which as he grows older will make him better than he now is. If a man with advancing years, knowledge, and experience cannot grow better, wiser, and more competent to handle the affairs entrusted to him, he has reached the full limit of usefulness, has begun to go to seed, and will not be wanted long in the world's activity.

I therefore assume that the men I am talking to and about are capable of being many times as good and effective as they now are. Effectiveness gets fairly weighed and compensated by the world's scales. No man is paid for what he is going to do. He is only partially compensated for what he has done. There must be a profit in everything, and therefore no man is paid as much as he is worth. His ability to perform must be bought at one price and sold for another. If he grows, his compensation will grow, and no small part of growth is the ability to rise and do the things that need be done, no matter what they are; to rise from selfishness to unselfishness, from smallness to greatness, with competency in all of the detail involved in these important advances.

Now let us get all of the men within any organization on the right track and get them going with a vis viva which is real and you will find effectiveness increased many fold. It will then be easy to exert these influences in a way which will enable the co-operative spirit to extend out to those less closely connected. Then it will be possible for our numerous organizations to achieve the co-operation we all desire. Begin at home and then go visiting.

Specific co-operation between men and corporations with divers interests is fraught with many embarrassments. The different concerns have not the same motive. They do not do exactly the same things. Their way of securing business is different. They appeal perhaps to a different set of customers. Some appeal to the few, others to the many. In some the constructive spirit predominates, in others the commercial. In some the motive is wholly that of manufacture and sale, in others it is engineering and professional. In some the essence or objectivity of the corporation resides principally under a roof, in others it is essentially in the field.

Nevertheless, all these differences are secondary to the fact that every man from the highest executive position to the lowest rank of authority is exerting human effort for one general welfare, within one broad field known as applied science and more specifically as engineering. They therefore differ less in their main

functions than the elements of daily practice would make it appear. Just as all mathematics can be reduced to a few rudimentary operations; just as the finest literature can be reduced to a few hundred words; just as variegated nature obeys a few fundamental laws — so can our seemingly diverse interests conform to a few essential requirements which, if faithfully carried out, will result in practical co-operation—hence useful.

The phases of co-operation as they arise may be casually considered as having several complexions. Co-operation is of but one kind. It is only the garb it wears which seems different. It may take the form of social entertainment between men in these various interests, among themselves or in the presence of customers, leading to good fellowship, mutual understandings, pleasantry, touch with affairs, and the general desire to do business together. This is a form of external co-operation, commonly known as "mixing," which is very desirable and too little cultivated.

Again, it may clothe itself in close relationship between officers, managers, and others in discussion of what best serves their respective interests; and the policies which they should adopt towards certain matters of mutual importance. Their resulting views should be judiciously passed down the line so that many may co-operatively partake of them.

Again, it may comprise engineering, constructive, and manufacturing relationships by which the apparatus or practice of one is made to fit and serve with that of the other, requiring a different co-operative effort from that which affects the more public interests.

It may often take the form of concessions for helpfulness to others. These may involve the spending of time, thought, care or money.

Under certain conditions, co-operation involves the use of foresight in perceiving what would be of benefit to another by way of imparting information, whether it concerns sales, data on costs, or the diligent apprehension of technical information which should be volunteered, especially where one has orders placed with another, or even to the apparently minor incident of promptly and sufficiently supplying a print, sketch, diagram, or other exposition of knowledge.

Some things are the little straws which, although small in themselves, are often greater in their importance than apprehended, and which properly handled produce a cumulative effect in co-operative desire.

Nothing is too small to co-operate upon. Nothing is too small to be good. No act too small to be kind and courteous. No man is able to know exactly what the result will be of anything he does. He thinks he knows, but he doesn't. The world has a way of judging what a man means by what he says, even though it doesn't size it just as he says it. Humanity is peculiarly adept at understanding people from their actions, especially their sustained and constant actions. Temporarily one may misjudge, but in the long run the old adage that "right wins out" is more true than the modern adage that "virtue is its *only* reward."

There are some things which distinctly make against co-operation. One is the mood of the man who is looking for trouble. Another is the characteristics of a man who is ultra-sensitive. Another follows from reticence, which of itself is not harmful, but which is a fruitful source of misunderstanding. The greatest is jealousy, personal and corporate.

Good memory has its advantages, but every man should be a good forgetter. A bit of reflection will show that many unsatisfactory events can never be cleared up, and life is too short to apply the last analysis to everything. Don't emulate Henry Ward Beecher's dog that chased a squirrel through a knot hole in a high board fence and stood there barking; then returned every day thereafter and barked a while at the hole.

It would be impossible in one short address to clear up the subject of co-operation and fit it to the many who must practice it. It would likewise be impossible to shape many minds to some rigid ideal of co-operation. It is my belief that the desired end can only be gained by a series of approximations, in which considerable patience needs be exercised, with much charity and some disappointment; while in the counteraction of reprehensible impediments, strong language and acts are warranted.

I believe it is necessary for our interests and every man in them to acquire a high ideal of co-operation, and not a limited, narrow, and selfish view. Without this, it cannot prosper. There is no difficulty in right-minded men acquiring this standard.

In detail application, the problem is more difficult. With our personal limitations and shortcomings, we can only approximate a fair result, but through patience, principle, and motive this practice can grow better every year until in fair season we will have a co-operation which in terms of usefulness will probably have an efficiency quite equal to that of any apparatus with which we deal.

If any man's co-operative efficiency is low, he had better regard it in exactly the same light as he does any deficiency which is equally wasteful, and that too before he is reminded of it.

Why this co-operation? Why not all split apart and each go our own way; not making the effort or the struggle for these things which I have tried to plainly state? Why not? The answer is, that is another way, which also has some merit. In fact, so much could be said in favor of it, that, without attempting a firm opinion, I am inclined to think that a consistent segregation of interests, with no attempt whatever at co-operation, would be better than any unreal, unsystematic, and half-hearted attempt which in the name of co-operation could only be a dangerous ally or a treacherous friend. We must have the real thing or nothing, and it must extend from the top to the bottom.

The head of our associated interests has long desired this real co-operation—the useful kind. He has done all he could to inspire. It is impossible to expect that his time can be given to its conduct, or even its general guidance. The officers and managers in authority in the various departments of his concerns must make it a burden upon their minds, a mission in their hearts, a motive in their life's work, and then we will get a fountain from which something will flow.

Meanwhile there is no use blaming the lesser lights for failure to co-operate if they see no very brilliant co-operative stars in the constellations above. This problem is right square up to every one of us, and it is also up to us to take a bit of what is briefly known as backlash in connection with it. We should have no feeling of resentment towards one who says we did not co-operate in a given matter. If we think we did, we should try to state why. If we think we did not, or if we have done something inadvisable, we should do the best we can to correct it. If in our interests there should be more plain talk and less imagination, more accuracy and less misinformation, haziness, and half-answer; more confidence and no jealousy; more of the spirit of the real desire to be helpful and less of selfishness; we would more nearly fulfill the ideals which our leader has in mind when he urges co-operation between those who are working in his interests.

Admitting one selfish thing, it may be said that certain benefit comes to the man himself whereby for his own personal interest he can afford to pay heed to these things, independent of the good it does his concern. But far above this there is a trust imposed upon

every man who works for an aggregation such as our lot is cast with. If any one does not think so, he had better get out and work for himself. When working in a big interest like this, you are working for it and not for yourself. You may be rewarded on merit or otherwise, and your virtues and abilities may be appreciated in some form or another, but you can't get away from the fact that you are not working for yourself. You are working for a complex and extended interest, one part of which pays your salary and all of which is what has been created by one man in forty years. If you can't work with all of this interest and for the interest of it all, you are doing just that much less than your full duty. You may have a hundred acts to perform for your own organization to one that you need do for any other, but that one is of added importance, because its rarity makes it a larger percentage of the total acts of like kind you will ever have opportunity to perform.

There is a wrong notion in the world as to the sequence of some things. You must first perform and re-perform and prove that you can perform and keep it up before you will get credit for performing. A large proportion of people in the world can't do certain things because they never tried, and many have thought they could not because they did not do very well the first time they tried. There isn't anything pertaining to the general conduct of himself in the world that a man can't do, and any man will make of himself just what his motives lead to. Consciously or unconsciously, his motives make him, and his practice will follow from what he has been made. Therefore useful co-operation must first rest on the underlying principles of co-operation. It must then be made individual within every man, practiced daily, and followed with persistence until we have the kind of co-operation which will usefully serve all these associated interests, and which is the kind that Mr. Westinghouse wants.

WINDING OF DIRECT-CURRENT ARMATURES

A. C. JORDAN

A DETAILED description, given by an actual workman, of the various operations performed by an armature winder, accompanied by precise directions and data is not without unusual interest. The types of armatures to which this description apply are those used in direct-current railway motors, crane and hoisting motors, vehicle motors, bipolar motors and belted generators up to 100 kw capacity.

TOOLS

The tools used by an armature winder are as follows:

1 shoe knife,
1 pair seven-inch shears,
1 pair eight-inch pliers,
1 ten-inch screw driver,
1 three-pound rawhide mallet,
1 small steel riveting hammer,
1 wedging tool (See Fig. 1),
1 heavy steel drift (See Fig. 2);
Also an assortment of fiber drifts of varying width, length and thickness (See Fig. 3).

The rawhide mallet is used in driving the coils into the slots by means of the fiber drifts, and in bending the coils into shape.

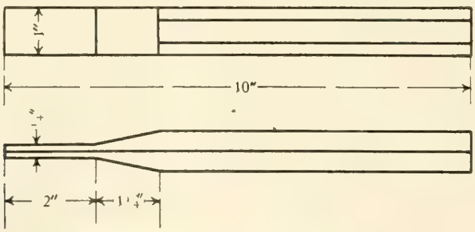


FIG. 1—WEDGING TOOL

The steel hammer is used for straightening laminations or finger plates. It should never be used in bending coils or on any of the drifts.

The wedging tool made from a cold chisel, is used in driving wedges into the slots as a hammer would injure the insulation of the coils and might bend the laminations.

CORE

An armature core is built up of soft sheet steel laminations. These are stamped of the desired shape and carefully annealed.

The stampings are then built up and keyed to a shaft or spider and held securely in place by end plates. Ventilating spaces are left next the shaft or spider and air ducts are distributed at intervals through the punchings by putting in spreaders to hold the laminations apart. The armature in rotating draws in air through the

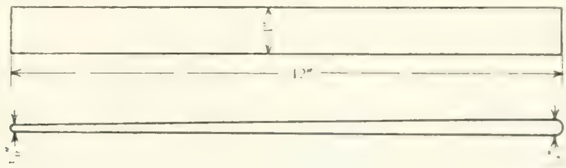


FIG. 2—STEEL DRIFT

ventilating spaces next the shaft and forces it out through the ducts, thus furnishing a simple and effective means of ventilation. After the core is assembled, the slots are filed to remove any projecting burrs—if these were not removed the insulation of the coil might be torn when a coil is driven into the slot and cause grounds and short circuits in the winding.

Operations Before Placing Coils on the Core.—The core is mounted in a winding lathe, as shown in Fig. 4.

If duck blankets are used they should be placed on the shaft before the core is placed in the winding lathe. If a block is used on the rear end of the armature core to shape the coils as they are wound or to protect the cast iron end-bell, the block should be

[illegible]

placed on the shaft before mounting in the lathe so that it will not be necessary to remove the core after it is partly wound. The core should be placed in the lathe with the commutator end at the winder's left. The commutator end of an armature may be distinguished by the key-way cut in the shaft next to the core for the commutator key; also on railway armatures the shaft opposite the commutator end is beveled and threaded to fit the pinion as in Fig. 5.

A description of the winding of a No. 38 B railv[illegible] will be given in detail.

The core of this armature is built on the shaft and has three ventilating ducts parallel to the shaft. There are 45 slots. These slots are relatively narrow as compared with the width of the teeth.

It will be seen from Fig. 6 that the end plate of the commutator end fits against a shoulder turned on the shaft. The rear end plate is held in position by a nut which is screwed on to the shaft and held in place by a set-screw.

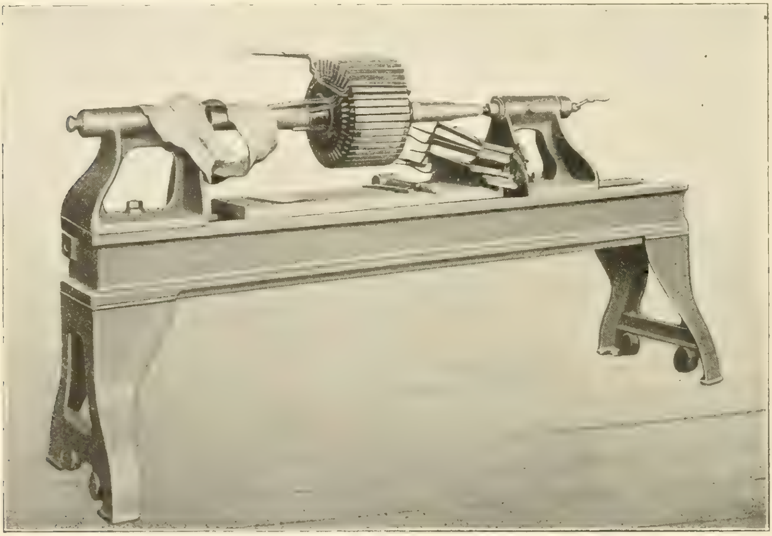


FIG. 4 ARMATURE IN WINDING LATHE

Two duck blankets are used on this armature. They should be placed on the shaft with the wider side of the blanket out and with the seam towards the core. The core should be inspected to see whether any of the laminations or fingers project into the

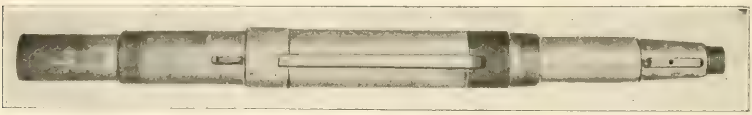


FIG. 5—ARMATURE SHAFT TURNED, THREADED AND KEYSEATED

slots. The steel drift and rawhide mallet are used to clear the slot of any of these projections.

CELLS

In each slot are placed cells of paraffined express paper. They are made of a width such that when folded and placed in

the slots the edges will project above the core, and thus protect the coils as they are placed in the slots. The cells are stiff enough so that when bent into the slots they are not easily shaken out, as the armature is revolved in winding. If any cells are longer

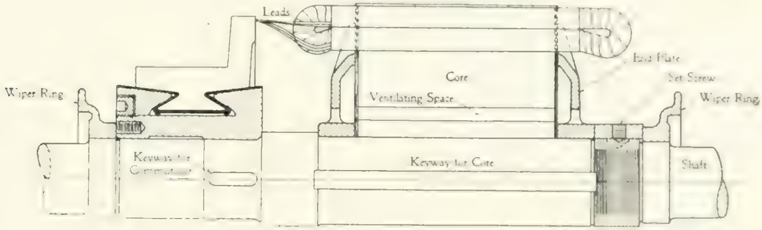


FIG. 6—CROSS-SECTION OF 38B RAILWAY MOTOR ARMATURE

than the slots they should be cut off so that both ends of the cells will be flush with the ends of the slots.

COILS

In winding this armature, 45 complete coils are used. Each coil, i. e., complete coil (See Fig. 7), is made by assembling in a cell three individual coils each consisting of two turns of No. 9. double cotton covered wire. Each slot contains one side of each of two different coils. One side of a coil is put in the bottom of one slot and the other side in the top of another slot.

Three wires or leads are brought out from each side of the coil on the under side. This type of coil is known as a "three-lead coil."

TAPING

The middle lead of the three coming from the bottom side of the coil is taped with black tape, the outside lead is taped with white tape and then all three leads are taped together. The top leads are not taped but are bent up and outward, as shown in Fig. 8.

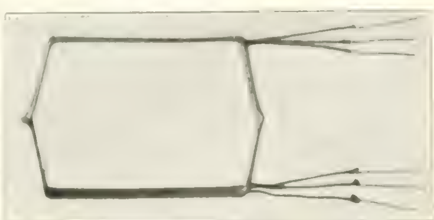


FIG. 7—TOP VIEW OF COIL

PUTTING COILS IN THE SLOTS

Beginning with any slot the bottom of a coil is placed in it so that each end of the coil is at an equal distance from the core, the top of the coil resting on the core. The bottom of the coil is forced to the bottom of the slot by means

of the fibre drift and mallet. Call this slot No. 1, and count towards the top of the coil until slot No. 11 is reached. Start the top of the coil in this slot. This is called a throw of 1 and 11, or simply 11. The tops of the first ten coils are not forced into the slots as they must be taken out when the last ten coils are put in place (See Fig. 8). The bottom of the next coil is placed in slot No. 45, and the top in No. 10. After the first eleven coils are in place the tops should also be driven into the slots. Continue in this manner around the armature until slot No. 11 is reached. Beginning with slot No. 45, take out the tops of all the coils up to and including the one in No. 11 slot and bend

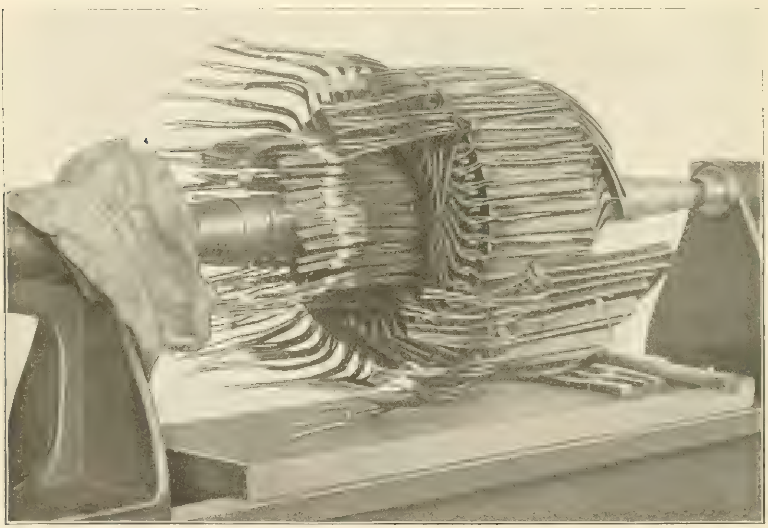


FIG. 8—TOP OF FIRST ELEVEN COILS THROWN BACK TO ALLOW THE LAST TEN TO BE PUT INTO PLACE

them away from the armature so that the bottom sides of the last ten coils can be placed in the slots. After the last ten coils have been placed in position, the tops of the coils which were removed to make place for the last ten coils are put in place.

A piece of heavy wire is wrapped around the coils at each end just outside the core and tightened with the pliers as firmly as possible. This is to hold the coils in the slots while the winding is being tested, trued and connected. If the upper leads are not bare at the outer ends, the insulation should be scraped from them for about three inches. All the upper leads are then con-

nected by a fine copper wire. Care must be taken that no leads touch the core or shaft as the leads are not required to be in-

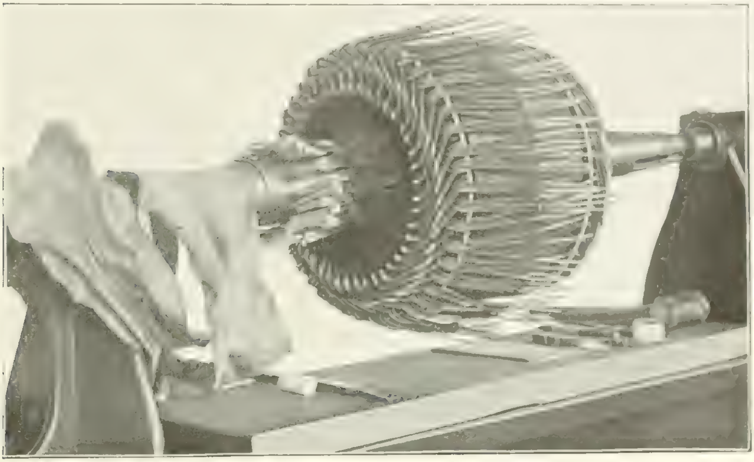


FIG. 9—ARMATURE WINDINGS BEING TRUED. WHITE MARKS SHOW WHERE WINDING IS TRUED

sulated sufficiently to withstand the voltage used in the insulation test. This test consists in applying 3 600 volts between the wind-

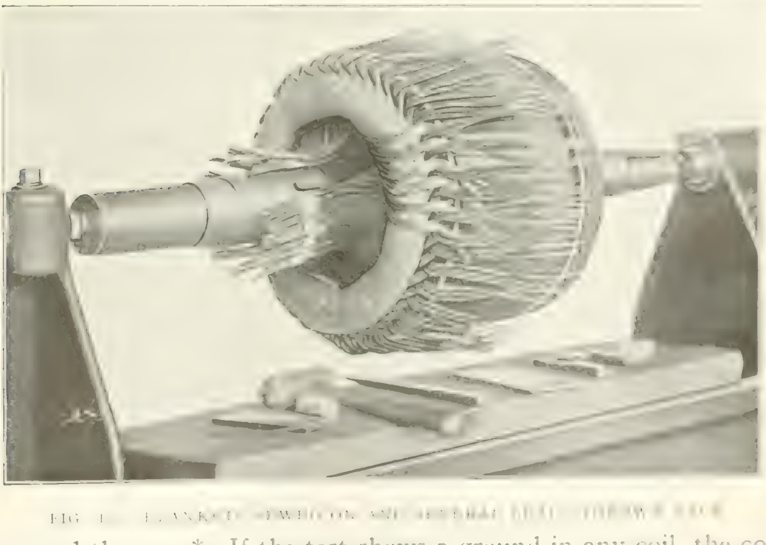


FIG. 1[illegible]

ing and the core.* If the test shows a ground in any coil, the coil is removed and a new one substituted.

*See *The Electric Club Journal*, Vol. I, page [illegible]

After the armature has passed the insulation test, the tops of the slot cells are cut off even with the core. Then the tops and ends of the coils are trued. To do this the armature is revolved in the lathe and a piece of chalk is held so that in turning the armature it will mark the coils that project. These are then driven down, or the others are brought out even with the high ones. The fronts of the coils are then trued. In Fig. 9 parts of the winding being trued are marked with white chalk.

The blankets are next fitted over the front ends and sewed on with a curved needle and wax thread. The thread is passed in under the ends of the coils and brought up through them near the core and tied firmly over the blankets. They should be tied in at least six different places. The blankets are to separate and

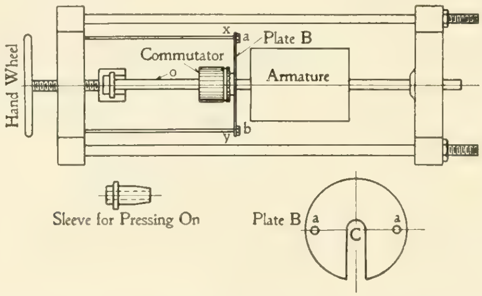


FIG. 11—HAND PRESS FOR PRESSING COMMUTATORS ON SHAFT AND FOR REMOVING COMMUTATORS. SLEEVE FOR PRESSING ON AND PLATE USED IN REMOVING

insulate the leads from the ends of the coils after the leads are connected to the commutator (See Fig. 10).

The winder then stands on the opposite side of the lathe and takes the bottom lead of any coil and counts seven slots in a clockwise direction facing the commutator. This lead is bent up and across the ends of the coils and held in place by the lead from the seventh slot. Proceeding in the same manner around the armature in a counter-clockwise direction facing the commutator, all of the lower leads are bent like the first one and secured by the upper leads. This finishes the operation of winding. The armature is now ready to have a commutator pressed on.

PRESSING ON COMMUTATORS

Small commutators are pressed on to the shaft by a hand press. All of the larger commutators are pressed on by means of a power press.

In Fig. 11 is shown a hand press. The plate *B* is used in removing old commutators. It is placed back of the commutator as at *x y* with the slot *C* over the shaft. Bolts *a b* are passed through the holes *a a* in the plate and secured by nuts. The commutator can then be forced off the shaft. In pressing on a commutator, a sleeve is placed over the shaft at *O*, and rests against the commutator. The rear end of the shaft is secured so it will withstand the pressure, and the commutator is forced on. The power presses are built on the principle of a hydraulic press. In pressing on a commutator a piece of babbitt metal or soft brass should be used against the end of the shaft. The shaft should be painted with white lead before having the commutator pressed on, in order to lubricate the shaft so that the commutator will press on easily.

The wiper rings are pressed on after the commutator and then the armature is ready to be connected.

CONNECTING

The first operation necessary in connecting is to "lay-off" the commutator.

In "laying-off" the upper and lower leads of any coil are found by means of a lighting-out set. The slots which contain this coil are marked with chalk.

In connecting a No. 38 B railway motor armature the following should be noted: There are 135 bars in the commutator. The throw of coil is 1 and 11 and, as the winding is progressive, the commutation throw $\left[\frac{\text{number of bars}+3}{2} = 69\right]$ is 1 and 69. With this commutator throw the center of the throw will be a bar. The throw of a coil is 1 and 11, therefore, the center of a coil throw will be a slot. Hence every slot should line up with a bar. By holding a pencil on the commutator perpendicular to it and sighting along the side of a coil the bar opposite the center of the slot in which the side lies may be located as at *A* in Fig. 12. Mark this bar with a colored pencil. Find the bar opposite the other side of the coil, as at *B*, and mark with the pencil, calling the slot in line with *A*, No. 1. Count 20 bars from *A*, in a clockwise direction and mark this bar No. 1. Also count 20 bars from *B* in a counter clockwise direction and mark this bar No. 69. Count from this bar to and including bar No. 1 and there should be 69 bars. Also there should be 29 bars between *A* and *B*. *D B A C* is called the forward throw and *D C* is the back throw. It is

seen that the back throw is 66 or three less than the forward, as it always will be in a four-pole, progressive wave-wound armature. If an armature is wound retrogressively the forward and back throws differ by one. If, in laying-off, the center of the slot does not come in line with a bar, find one that will line up with a bar and proceed as above.

The 38 B armature has three leads on each side of a coil and as there are 135 bars, there is no idle coil in this winding. Place the middle lead of the three coming from the bottom of slot No. 1 in bar No. 1, the outside lead in bar No. 135 and the inside lead

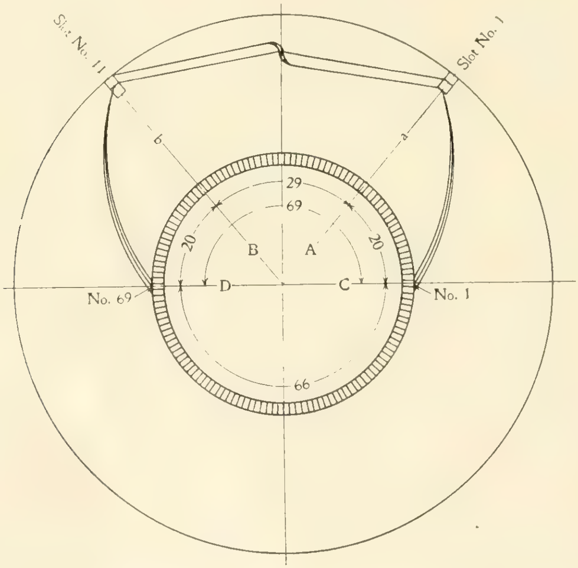


FIG. 12 COMMUTATOR LAID OFF, SHOWING BAR LINED UP WITH MIDDLE OF SLOT

in bar No. 2. Next take the lower leads from slot No. 2 and place them in bars No. 3, 4, and 5. The insulation should be removed from the leads where they are to be soldered to the commutator necks. They are driven to the bottom of the slot by means of a tool similar to the wedging tool only much thinner. The lower leads are all placed in the commutator and then they are "lighted-out."

Lighting-Out.—The purpose of lighting-out is to see that there are no grounds or short circuits between the bars or coils,

and to see if the leads are connected to the proper bars. The lighting-out set consists of two terminals connected in series with a 110-volt incandescent lamp to the 110-volt service lines.

One terminal of the lighting-out set is placed on bar No. 1 and the other on the middle lead coming from the top of same coil. The lamp should light. Next move the terminal on commutator bar No. 1 to bar No. 2 and if the lamp lights it shows a short-circuit between bars or between coils. If the lamp does not light the upper terminal is moved to the next lead counter-clockwise, when the lamp should light; if not, find the bar on which it will light and bring the wire connected to that bar to the proper bar. Continue in this manner around the commutator. After the winding is lighted-out, the ends of the leads projecting out over the commutator beyond the neck are cut off and saved as they are to be used again.

Two layers of friction cloth are then wound over the lower leads and then the upper leads may be connected. The center lead from slot 11 is connected to bar No. 69, the outside lead is connected to bar 70, the inside lead from slot No. 12 is to bar No. 71, and so on around the armature. After the leads are all placed in the slots in the commutator necks, they are driven to the bottom of the slots. The lower leads which were cut off are known as "dummies." These are driven into the tops of the slots until the slots are full. After putting in the dummies, all projecting ends are cut off and the armature is tested for grounds and short circuits.* The leads are then soldered in the slots and the armature is then ready for banding.

BANDING

Tinned steel wire is used in banding. The bands on the core are insulated with mica and fullerboard while on the coils they are insulated with Japanese paper and tape. The insulation is made wide enough so that it projects one-eighth of an inch on each side of the bands. The bands on the core and leads are five-eighths of an inch wide, while the ones on the ends of the coils are made as wide as possible. In putting on the bands the armature is rotated in a lathe and the steel wire is wound on under tension. Clips are placed under the band wires and after sufficient turns have been wound on, the clips are bent over the

*See *The Electric Journal*, Vol. I., page 115.

wires and soldered to them, so that the band wires are held firmly together. After the bands are all on, they are heated with a soldering iron and solder run around each band. Thus the wire and clips are held firmly in place.

Seven strips or bands are placed on the armature, four on the core, one on each end of the coils and one to hold the leads in place. These are shown in Fig. 13. The two bands on the rear end of the coils are connected to the last band on the core by

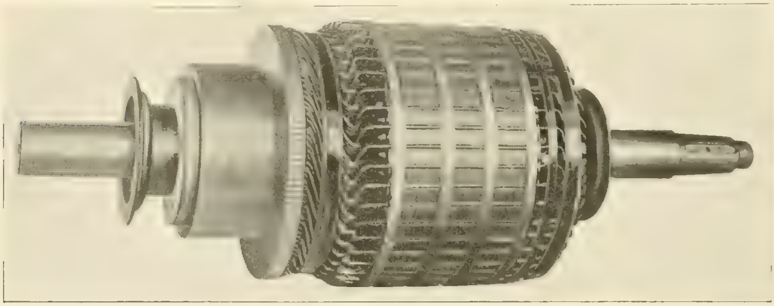


FIG. 13—COMPLETED ARMATURE

means of three anchor clips spaced equally around the armature. This is done so there will be no danger of the outer bands slipping.

After the armature is banded it is tested for short circuits or grounds, given a coat of insulating paint and is then ready for assembling with the other motor parts.

INDUCTION MOTOR CHARACTERISTICS BY THE VECTOR DIAGRAM

H. C. SPECHT

THE purpose of this article is to give a practical example of the use of the vector diagram in working up the characteristics of an induction motor. The difficulty of making a satisfactory brake test and the inadequate method of calculating the power-factor together with other inaccuracies are obviated by use of this diagram.

In working up the characteristics of a given motor, but three careful measurements are necessary.

First: The resistance of the primary winding, preferably after the motor has had a heat run at full load.

Second: The primary amperes and watts input while the motor is running at no load and full voltage.

Third: The primary amperes and watts when the motor is locked, such voltage being used as to give a current which will not heat up the windings more than a continuous heat run at full load. Then the amperes and watts for full voltage may be calculated by taking the current in direct proportion to the voltage and the watts proportional to the square of the voltage.

From the result of these measurements are calculated the necessary data for constructing the diagram. To check the results obtained by the diagram, pull-out and slip readings at full load are taken by test. In the case of motors of large size where the slip at full load and pull-out might be difficult to take, a check of efficiency by losses is made.

To illustrate the practical application of the diagram method an induction motor test is given in detail.

Motor—2 hp. three-phase, 200 volts, 60 cycles, 4 poles.

No-Load Reading	Locked Reading
E = 200 volts	E = 200 volts
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Hot resistance of one leg = r_1 [illegible] .857 ohm

[illegible]

In Fig. 1 from O as center and with a radius of 100 parts, draw a quadrant. The vertical direction is that of the impressed voltage. Lay off to a convenient scale the no-load and locked current vectors OC_O and OC_L in the direction of their respective

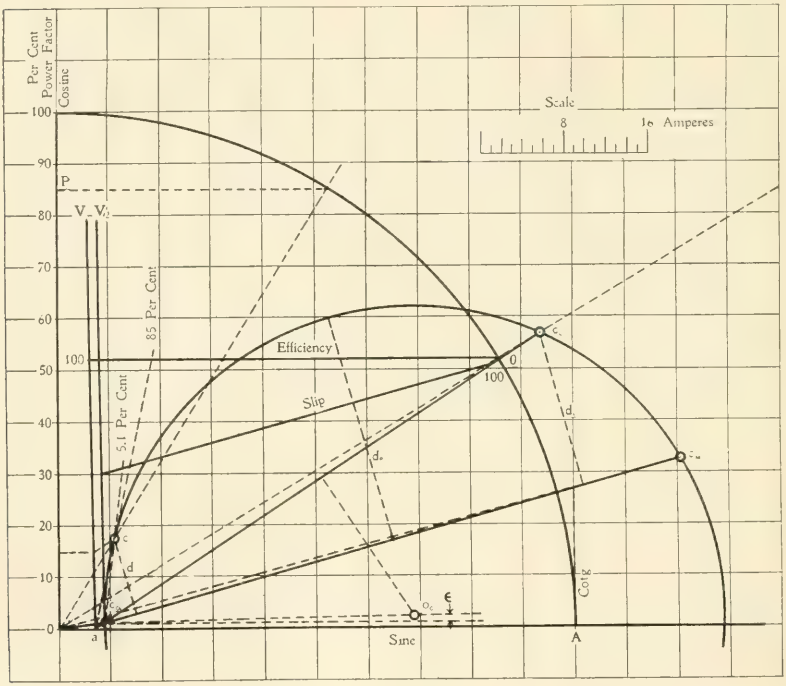


FIG. 1

power-factors, 10.5 per cent. and 52 per cent. measured perpendicularly from OA to the intersection with the power-factor circle. Draw the line C_OC_L to its intersection with the base line at a. Then from C_O lay o the line C_OO_C making an angle tan ε = .019 with the base line OA. The intersection of the perpendicular to the middle of C_OC_L with the line C_OO_C is the centre of the current circle C_OCC_L.

Tangent to the current circle at C_O erect V_2, the base line of the secondary loss. From the point a and parallel to V_2 draw V, which is accurate enough for motors above one horse-power. Between lines V and C_OC_L and parallel with the base OA

draw the efficiency line to a scale which can be divided conveniently into 100 parts.

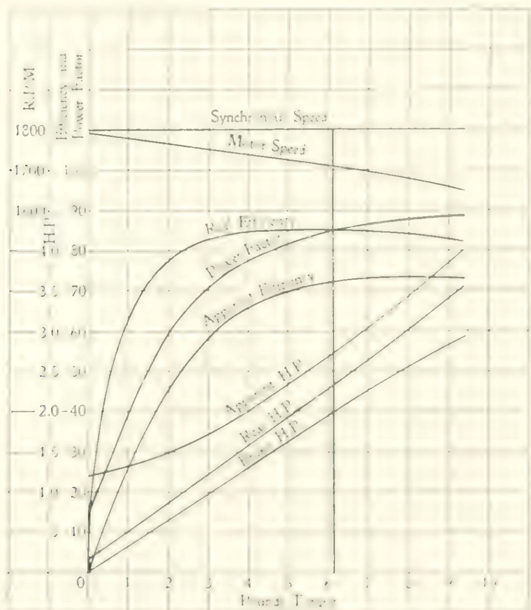
$$X_1 + X_2 = \frac{\sin \Phi\ I \times E}{I_1} = 8.15 \text{ ohms}.$$

X_1 = primary inductive resistance of one leg

X_2 = secondary inductive resistance in terms of primary.

$$\operatorname{cotg} \Phi_M = \frac{r_1}{X_1 + X_2} = .272$$

Draw OC_M to its intersection with the current circle at C_M making the angle $\operatorname{cotg} \Phi_M = .272$ measured perpendicularly from



the point A. Connect C_O with C_M. Between lines V_2 and C_OC_L and parallel with C_OC_M draw the slip line to 100 per cent. scale.

Perpendicularly above OA on V lay off the full-load current corresponding to a power-factor and real efficiency of 100 per cent $= \frac{\text{hp} \times 746}{E} = 7.54$ amperes. The intersection with the current circle of a line projected from this point and parallel with C_OC_L gives the full-load current point. Then OC represents the full-load current in length (= 10.3 amperes) and direction. A line drawn from O through C intersects on the quad-

rant the corresponding power-factor = 85.2 per cent. A line from a through C indicates the efficiency in per cent. on the efficiency scale and a line from Co through C gives the slip in per cent. on the slip scale.

In the same way the data for one-fourth, one-half, and one and one-fourth and other loads may be obtained.

All other values such as brake hp, real hp, input, etc., may be calculated and tabulated as follows:

Values from Diagram				Values by Calculation					
Amperes	Power-factor	Real efficiency, per cent.	Slip, per cent	Apparent horse-power $= \frac{I \times E}{746}$	Real horse-power = apparent horse-power x power-factor	Brake horse-power = real horse-power x real efficiency	Apparent efficiency $= 100 \left[\frac{\text{Brake horse-power}}{\text{Apparent horse-power}} \right]$ per cent.	Speed $= \frac{(100\text{-slip})}{100} \times$ Synchronous speed	Pounds torque $= \frac{\text{Brake horse-power} \times 5\,250}{\text{Speed}}$
5.18	50	72	1.55	1.39	.694	.5	36	1772	1.48
6.42	70.5	82.7	2.67	1.72	1.21	1.0	58.2	1752	3.0
8.2	80.3	84.8	3.9	2.2	1.77	1.5	68.2	1730	4.55
10.3	85.2	85.2	5.1	2 76	2.35	2.0	72.5	1708	6 15
14.7	88.7	73.3	8.33	3.95	3.5	2.9	73.4	1650	9.23

In Fig. 2 the different values obtained are plotted against pounds torque. The maximum perpendicular dp between $CoCm$ and current circle, divided by the perpendicular d $(=\frac{dp}{d}) =$ 2.96 is the pull-out torque times full-load torque; and the perpendicular dL divided by d, $= \frac{dL}{d} = 2.01$ is the starting

torque times full-load torque. The current which the motor would take to start with full-load torque at full voltage is

$$\frac{d}{d_L} \times \frac{\text{locked amperes}}{\text{full load amperes}} = \frac{1}{2.01} \times \frac{54.3}{[illegible]} = [illegible]$$

All the above data checked very well by test as well as by losses; for instance for full-load, the calculated real efficiency by losses is 85.3 per cent. and 85 per cent. by diagram.

By the above diagrammatic method much time can be saved and also errors cannot occur as in the method of calculating the values by losses. In addition the diagram shows directly, to one familiar with the use of it, for what purpose the motor can be used, or if anything is defective with the winding of the motor it indicates what is wrong. For instance:

1. If some coils are reversed, then the no-load current vector OC_0 will be very great compared to the locked current and the power-factor of the locked current will be high.

2. If a motor has some coils short-circuited or a motor has not enough turns of winding, then no-load as well as locked current will be high and therefore pull-out torque will be high and slip and power-factor low.

3. If a motor has normal turns of winding but too high primary resistance and normal secondary resistance, then the no-load vector OC_0 will be normal but the locked current vector OC_L and vector OC_M will be smaller. Their power-factors will be higher and that of OC_M will be more than that of OC_L. Therefore the efficiency and starting torque as well as pull-out torque will be low due to high primary drop. In this case the slip at equal load will remain almost constant.

4. If a motor has high secondary but normal primary resistance, then the power-factor of the locked current will be high but the power-factor of OC_M will be normal, since it depends only on the primary ohmic resistance and total inductive resistance. Therefore, in this case we have a motor of high slip, high starting and normal pull-out torque and low efficiency. This motor would be suitable for use in crane service.

NOTE.—An elaborate and detailed dissertation on this subject with particular application to single-phase and very small polyphase induction motors may be found in the Electrical World and Engineer of February 25, 1905.

PROTECTIVE APPARATUS

FOREIGN PRACTICE—LIGHTNING ARRESTERS

N. J. NEALL

IT is safe to say that protective apparatus for the security of transmission of electric energy against lightning and other static disturbances, has had its birth and greatest development in America. It was here that all the pioneer problems in transmission were worked out—among these being the noted labors of Elihu Thompson and Wurts. With one exception, that of the horn arrester, the apparatus offered abroad for this purpose impresses one, first by its similarity in principle to that developed in America, and secondly, by the petiteness of its working out. In America designs are rugged; in Europe they are refined.

In order to facilitate a description of the principal forms of arresters used abroad they will be classified as follows:

LOW VOLTAGE

1. Magnetic blow-out.
2. Moving part—magnetic torsion.
3. Coherer type—loose.
4. Multigap.
5. Horn type.
6. Water column.

HIGH VOLTAGE

1. Multigap.
2. Coherer type—loose.
3. Horn type.
4. Water column.

American Makes.

Multigap with resistance.
Multigap with non-arcing metal.
Multigap with non-arcing metal, and resistance on low equivalent principle.

LOW VOLTAGE

1. Magnetic blow-out. (Suitable up to 650 volts for either direct-current or alternating-current service.)

The arrester shown in Fig. 1 will be recognized as another form of the well known magnetic blow-out type of arresters. In this case, two gaps work in series permitting a direct static discharge to ground. One of the gaps is so shunted by a magnet coil as to cause the arc in the other gap to blow out. A resistance is added to control the flow of current.

2. Moving part by magnetic torsion (System Bubeck). (Suitable for either direct-current or alternating-current service up to 650 volts.) (See Fig. 2.)

In this arrester one of the two electrodes forming the discharge-gap is movable. When the static discharge is followed by current, an

FIG. 1—MAGNETIC
BLOW-OUT TYPE
LIGHTNING ARRESTER

electromagnet is excited which causes the movable electrode to turn on its axis and thus break the arc. After this a spring causes the electrode to resume its normal position for further operation. The whole arrester is mounted on porcelain and can therefore be used for outdoor as well as for indoor mounting.

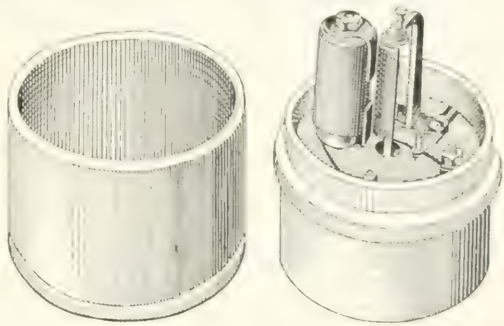


FIG. 2—MOVING PART—MAGNETIC TORSION-TYPE OF LIGHTNING ARRESTER (SYSTEM BUBECK)
The terminals of this arrester are brought out on the under side of the part shown on the right.

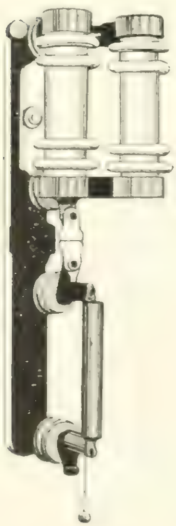


FIG. 3 — COHERER
LIGHTNING
ARRESTER,
LOOSE TYPE

3. Coherer type—loose. (System de Compagne de l'Industrie Electrique et Mecanique.)

The important element of this type of arrester is a porcelain tube filled with a "powder," which offers a considerable resistance to normal current, but allows a momentary static disturbance to pass over it easily. This arrester is therefore non-arcing in the sense that no arc is allowed to form, although they constantly drain the system on which they are placed. In order to avoid any possible holdover, a fuse is provided as shown.

Fig. 3 shows a form good up to 1 000 volts. Above 10 000 volts these units are placed in

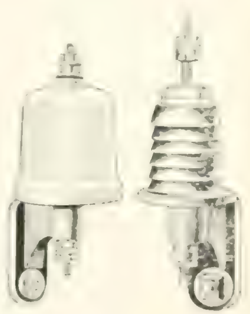


FIG. 4 — [illegible]
LIGHTNING ARRESTER,
BELL TYPE

series between line and ground, only one fuse being required.

For the reason that several arresters in parallel at any one point are better than one, especially on large systems, a number of the powder filled units are placed in parallel.

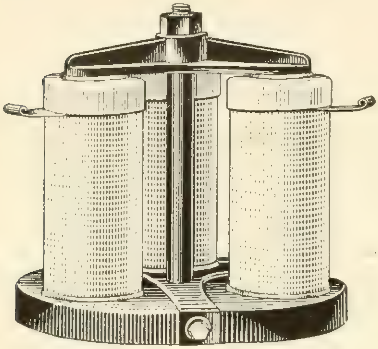


FIG. 5—MULTIGAP LIGHTNING ARRESTER. DISC TYPE (SYSTEM BROWN, BOVERI & CO.)

4. Multigap. (a) Bell type. (Good up to 250 volts direct current, or 600 volts alternating current.) (See Fig. 4.)

This arrester derives its name from its bell-like shape, as well as from the specially shaped pieces of zinc which are applied one on the other but separated by pieces of insulating material in such a way as to form many small gaps between the flaring edges of the discs. The action in suppressing the arc will be recognized by the readers of these articles as that depending upon the use of multigaps of a non-arcing material. The porcelain cover is designed to keep out moisture and renders the arrester suitable for mounting outdoors as well as for station use.

(b) Disc type. (Brown, Boveri & Co.) (May be used on transmissions up to 3 000 volts.)

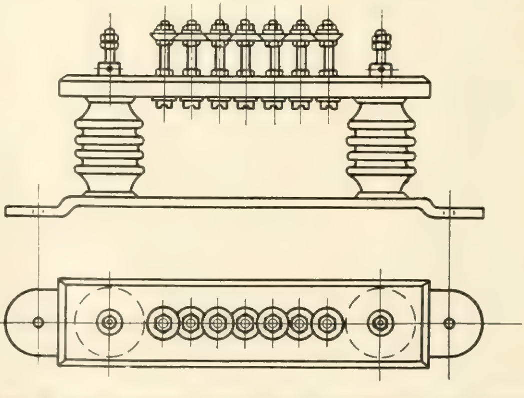


FIG. 6—MULTIGAP LIGHTNING ARRESTER, CONE TYPE

This arrester like the preceding consists of alternating zinc discs and mica washers arranged one above the other and varying in number according to the voltage of the service for which it is designed. The column as a unit permits an easy arrangement for any commercial service. For example, the type shown in Fig. 5 is a three

pole mounting for three-phase service. In operation the static discharge to ground is expected to pass down over the surface of the discs as well as between them, while the current following

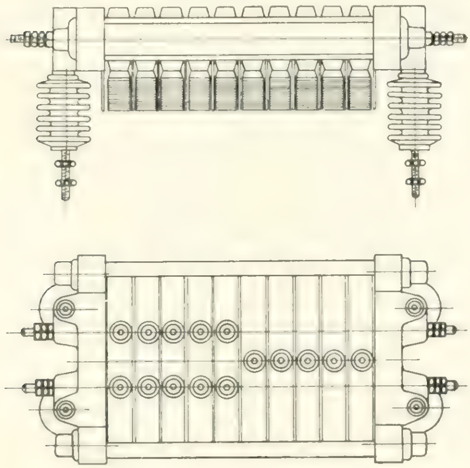


FIG. 7. MULTIGAP LIGHTNING ARRESTER, DISC TYPE (SIMILAR TO WURTS' METHOD)

takes only the gaps formed by perforation of the mica between the discs. The well known multigap non-arcing metal principle thus comes into operation to suppress any short-circuit arc. This type is suitable only for indoor mounting.

(c) Cone form. (May be used up to 36 000 volts.) (See Fig. 6.)

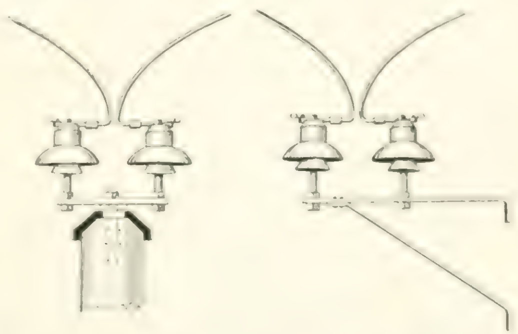


FIG. [illegible]

Recommended abroad for service up to [illegible] volts. The same type has been used in America for even higher voltages.

In this arrester the gaps are cone shaped to give a maximum number of gaps in a minimum of space. This arrangement, moreover allows for a certain individual adjustment of the gaps according to the voltage. A resistance is recommended for use with this arrester.

(d) Multigap—Disc type (similar to Wurts method).* (May be used from 2 000 to 20 000 volts.) (See Fig. 7.)

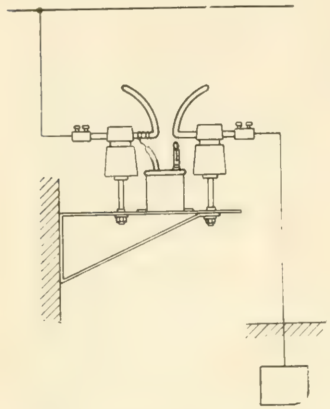


FIG. 9—A METHOD OF INCREASING THE EFFECTIVENESS OF THE HORN LIGHTNING ARRESTER AT LOW VOLTAGES BROUGHT OUT BY THE LAND UND SEEKABELWERKE ACTIENGESELLSCHAFT, COELU, NIPPES

This arrester consists of a number of grooved zinc cylinders and grooved zinc plates, the number depending on the voltage. These are spaced alternately and slightly separated. The parts are held rigidly downward by means of a porcelain support as shown, with the idea that when a discharge passes, the metallic particles could be easily thrown out and thus not affect the gap. A resistance must be used in connection with this device.

5. Horn style. (Fig. 8.) This lightning arrester is distinctly European, both in origin, development and use. Oelschlaeger did a great deal to perfect it and really brought it to its present shape. The principles governing the operation of this arrester are well understood and need no repetition here. As a style it has suffered from several defects, namely:—On low voltage the opening is so small as to make it difficult to keep the gap constant; dirt, dust, bugs and even beading of the wire causing this to change. On high voltage the pressure necessary to break it down and yet successfully interrupt the arc is necessarily so high as to confine its operation to severe discharges only.

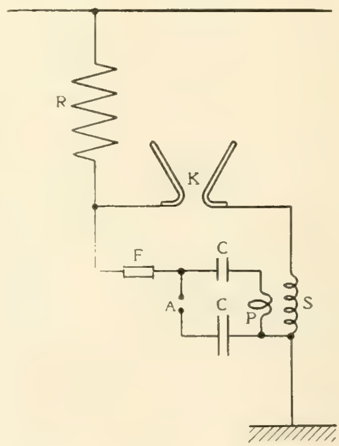


FIG. 10—LIGHTNING ARRESTER RELAY ANOTHER METHOD OF INCREASING THE EFFECTIVENESS OF THE HORN LIGHTNING ARRESTER AT LOW VOLTAGES

To facilitate its operation at low voltage several important changes have been made in its construction;

*See *Electric Journal*, Vol. II., page 35 and page 376.

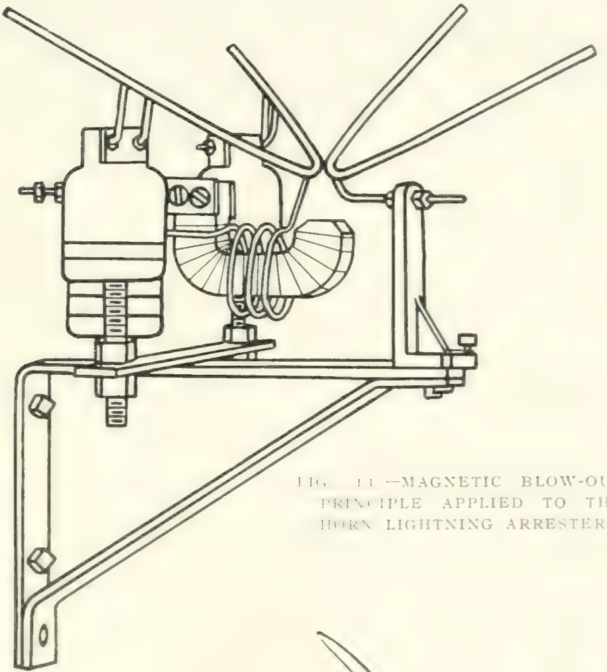


FIG. 11.—MAGNETIC BLOW-OUT PRINCIPLE APPLIED TO THE HORN LIGHTNING ARRESTER

one of these consists of an auxiliary gap, (Fig. 9), shunting the main gap in such a way that the break down is easily promoted but owing to the auxiliary gap being in series with a high resistance very little current flows over it. The spark ionizes the air sufficiently to start the main arc.

A further modification is shown by Fig. 10. It is called the lightning arrester relay. The name is derived from the action of the circuit, *R-F-C-P-Ground*, at the time of a static discharge over the arrester. As

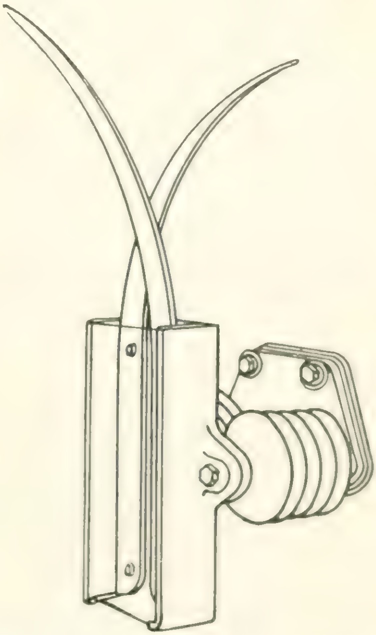


FIG. 12.—HORN LIGHTNING ARRESTER
(SYSTEM LAHMEYER)

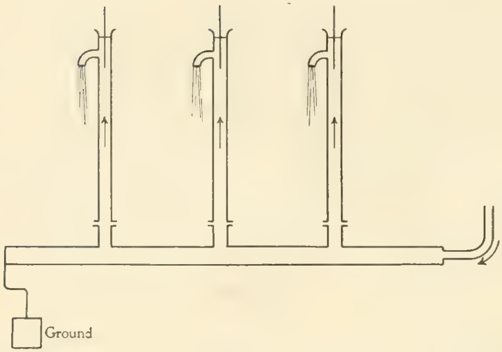


FIG. 13—WATER COLUMN LIGHTNING ARRESTER USED BY THE HYDRO-ELECTRIC COMPANY OF VIZILLE, FRANCE

A terminal connected to each wire of the 10 000 volt three-phase system is immersed in the water as shown. This apparatus is said to consume five kw or about three-tenths of an ampere per column. In addition to the water columns, choke coils are used at the terminals of the generators and at substations; also horn arresters with water resistances in series.

soon as the condenser *C* reaches the potential to which the auxiliary spark gap *A* has been set, the latter is broken down and a resonating condition ensues which excites the primary winding *P*, of the high frequency transformer. This in turn causes the secondary to take a high voltage which breaks down the main gap. By this means gap *K* can be set to three or four times the opening otherwise required for break down at 2 000 or 3 000 volts. This principle can be utilized up to 6 000 volts.

Another defect of the plain horn arrester arises from the lack of positiveness in breaking short-circuits, a slight change in inclination of the horns causing a "jump back" of the arc. The magnetic blow-out has been applied to meet this in the manner shown in Fig. 11.

Another modification of the horn arrester is shown in Fig. 12, where one of the lectrodes is provided with a carbon facing, by means of which the gap is less affected by passing current. For this form a resistance is recommended for use in series with the gap. This arrangement of the horns permits economizing of space. Glass shields promote a draft for the operation of the arrester.

6. Water column.

The illustrations Figs. 13, 14 and 15 show clearly the foreign application of this well known principle. The working out is neat and with a pure water supply of constant quality might be entirely satisfactory.

HIGH VOLTAGE

In the foregoing description the types suitable for high voltage work are indicated. In addition to these, the invasion of the foreign market by American electrical manufacturing companies has led to considerable use of the apparatus exploited by them for such service. Descriptions of Italian high tension lines, particularly, show the presence of such types.

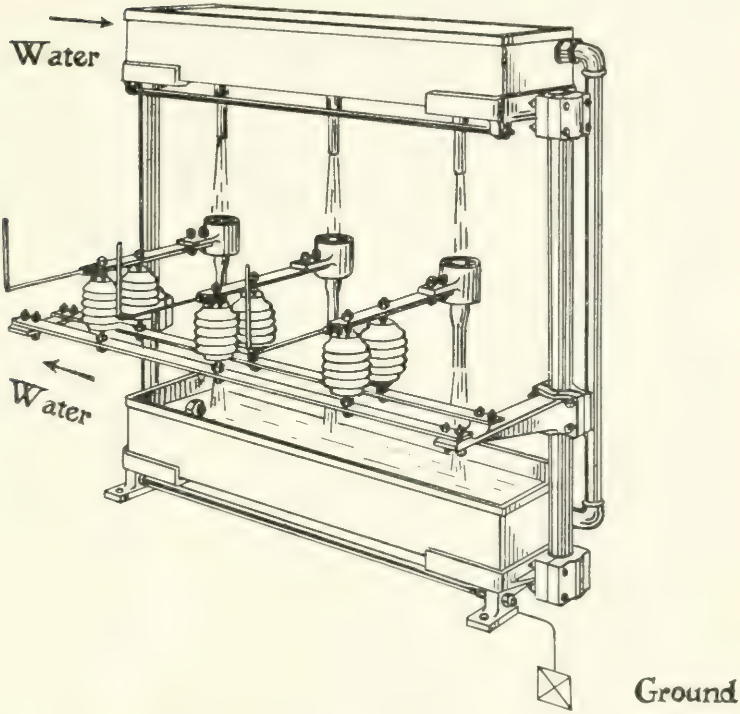


FIG. 14—WATER COLUMN LIGHTNING ARRESTER USED BY THE CAMPAGNIE VANDOISE DES FORCES MOTRICES DES LACS DE JOUX ET DE L' ORBE

This type of arrester is used on a 15 000 volt three-phase line. In addition to the water columns a horn arrester with resistance in series is used. The construction shown is from the Oerlikon works and drains the line by means of a double water path to the ground for each leg of the system.

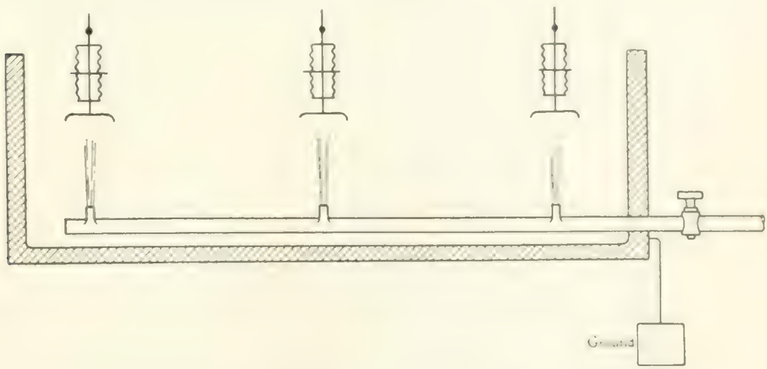


FIG. 15—WATER COLUMN LIGHTNING ARRESTER USED BY THE SOCIETE MERIDIONALE D' ELECTRICITE

In this arrester water jets play against pans connected one to each leg of the three-phase line.

DIAGRAMS OF SINGLE-PHASE CONTROL

R. P. JACKSON

SUPPLEMENTING the article in the September JOURNAL on "Single-Phase Alternating-Current Car Control," diagrams are here given which show standard single-phase equipments, one with hand control for single cars and the other with switch control for multiple-unit operation. Cars equipped as shown in these diagrams are in continuous and satisfactory operation. The external appearance and simplicity of the control apparatus is borne out by an examination of the apparatus itself. The motors are straight series-wound and the method of delivering power from the trolley wire to the motor involves apparatus of only the simplest type.

The whole purpose has been to make full use on the car

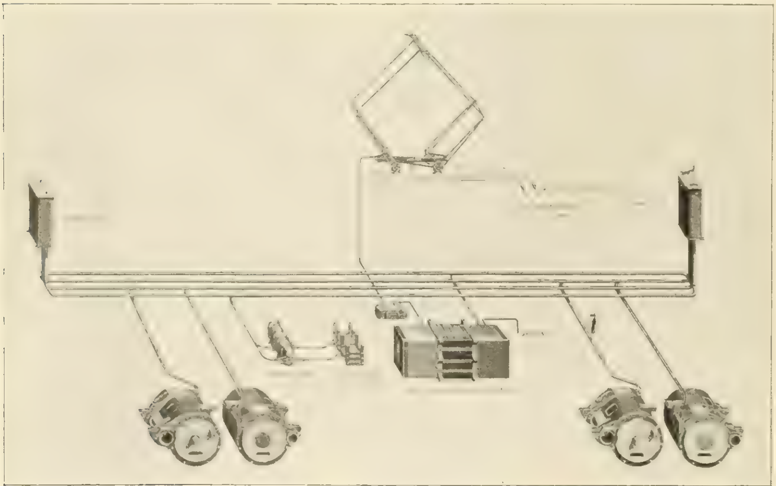


FIG. 1—SINGLE-PHASE EQUIPMENT WITH HAND CONTROL

as well as in the power transmission, of the simplicity of the alternating-current system. Single-phase cars are coming into general use for interurban service where skilled attendants are often not available. The small amount of care required by the cars and the ease of such repair work as may be needed are therefore desirable features. It is also important to reduce the total dead weight carried by the car to a minimum, and to keep the size and number of pieces of apparatus small; both to have the convenience of mounting and inspection, as well as to secure a neat looking car.

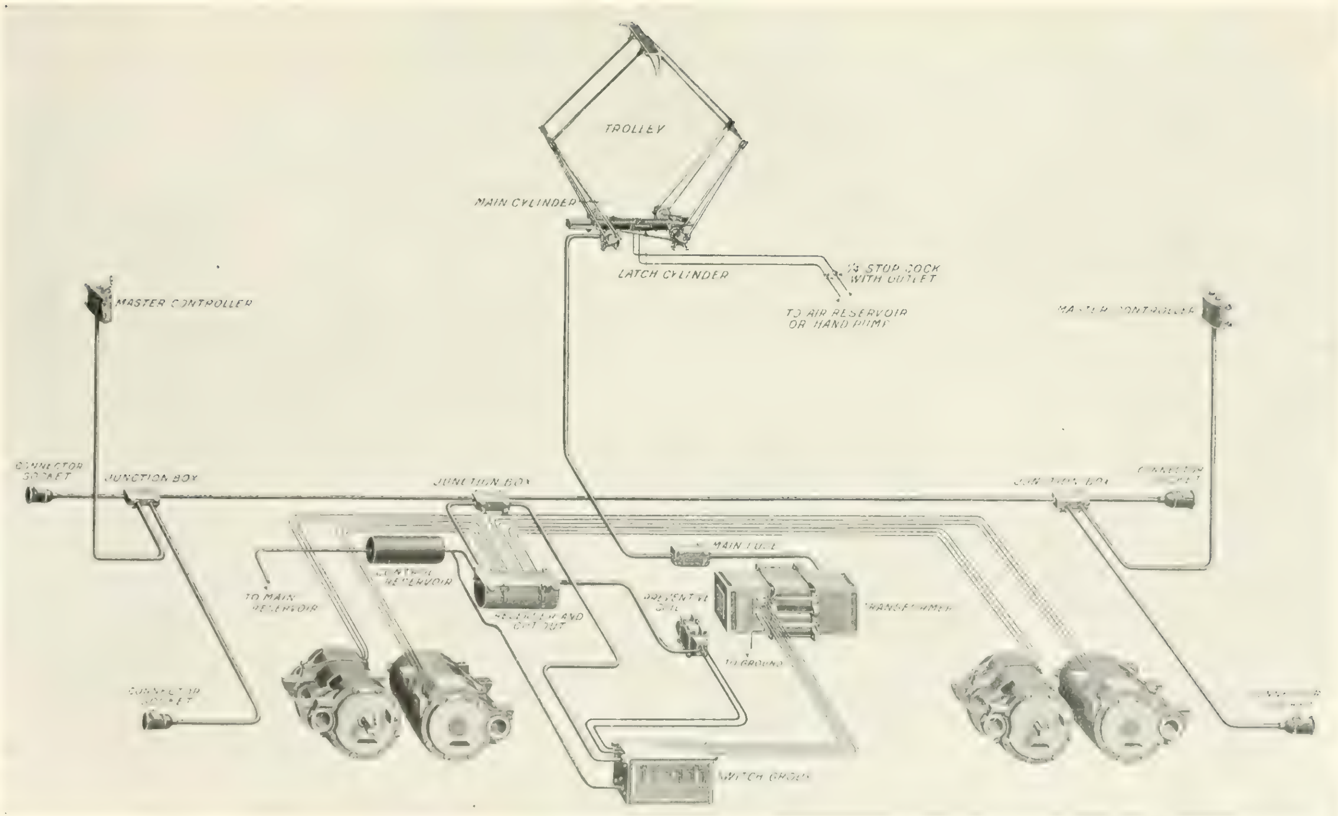


FIG 2—SINGLE-PHASE EQUIPMENT WITH MULTIPLE-UNIT CONTROL

SINGLE-PHASE LOCOMOTIVE TESTING

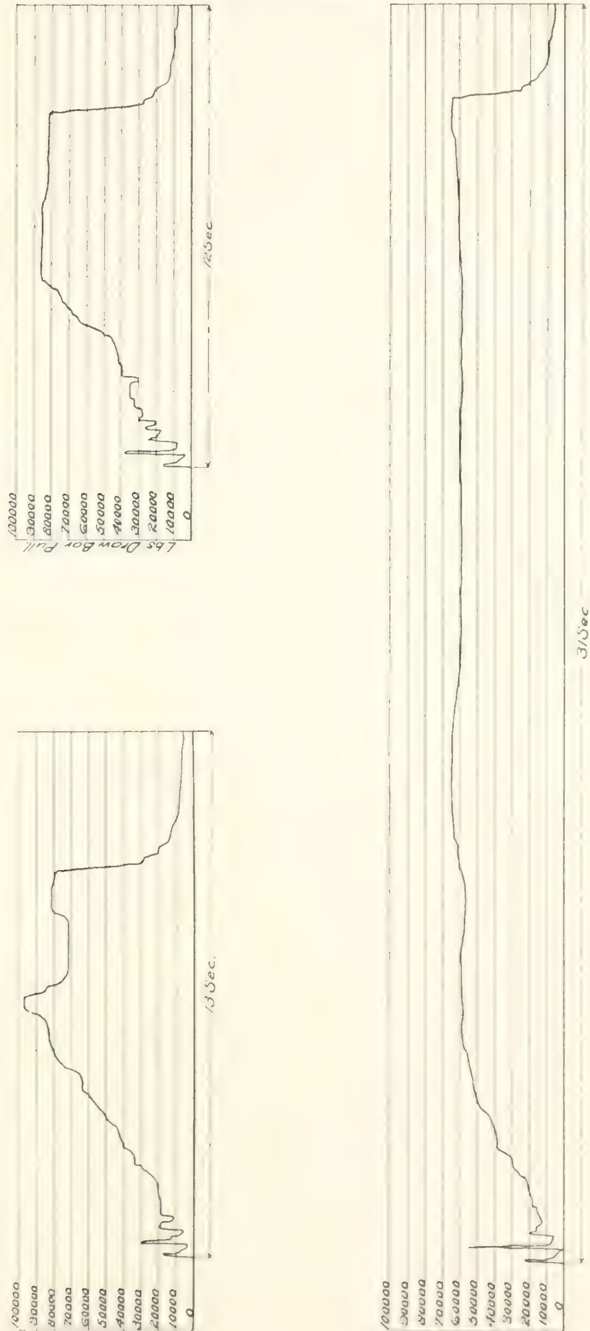
GRAHAM BRIGHT

IN testing electric locomotives a number of difficulties arise tha are not met in testing single motor cars. Locomotives are generally intended to handle a varying number of cars, therefore to make a complete test it is necessary to determine the various characteristics of the locomotive at several different loads and lengths of run. A dynamometer car should be used to determine the draw-bar pull while starting, accelerating and running. The dynomometer car, used in testing locomotives, automatically records the draw-bar pull or push, the time, speed and distance traveled.

Numerous tests have been conducted during the past few months on a large single-phase locomotive built by the Westinghouse Electric & Manufacturing Company. This locomotive consists of two units, each equipped with three 225 hp single-phase railway motors. The units can be used separately or together as desired. The motors are geared for slow speed freight service. The two units together weighed 136 tons.

In Figs. 1, 2 and 3 are shown dynamometer car records taken while using both units to draw a train of 50 new steel freight cars. The brakes on the four rear cars were set in order to obtain a high draw-bar pull. In the test shown in Fig. 1, by using sand, a maximum of 97 000 pounds was obtained. This gives a friction coefficient of 35 per cent. In the test shown in Fig. 2 a maximum of 87 000 pounds was obtained for an appreciable time with no indication of slipage of the wheels. The friction coefficient for this case was 32 per cent. In the test shown in Fig. 3 an average draw-bar pull of over 60 000 pounds was obtained for a considerable period of time without the use of sand and with no indication whatever of slipping. Although these curves show a gradual increase to a maximum draw-bar pull, this maximum could have been obtained in a shorter time, if desired, by operating the controller faster. The readings of the volts, amperes, real and apparent power, and speed were obtained in the same manner as described in the article "Tests on Interurban Single-Phase Equipments" in the November JOURNAL.

The curves plotted in Fig. 4 show the results of a test on one of the two halves of this locomotive. The load consisted of 14 heavily loaded freight cars of a total weight of 818.3 tons. The distance traveled was 19 000 feet. Readings on all instruments were taken every five seconds during the entire run. The power-factor


Lbs Draw Bar Pull
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
12 Sec
13 Sec.
31 Sec

FIGS. 1, 2, AND 3

and kw curves are separated from the volt, ampere and speed curves only in order to prevent any confusion that might result if all the curves were plotted together. The track on which this test was made is nearly level and has twelve curves of large radius. The controller was operated to the "full on" position in about 45 seconds and allowed to remain in this position until 320 seconds from the start. At 260 seconds a curve in the track was entered which accounts for the slight decrease in the speed curve at that point. A slight down grade on a straight track began at 290 seconds which caused a very noticeable increase in the speed. The current was cut off at the end of 320 seconds and the train allowed to coast. Owing to the slight down grade the speed remained practically constant until an up grade and reverse curve was encountered at 400 seconds which caused the speed to drop rapidly. At 450 seconds a slight down grade was reached which caused the speed to rise slowly. Level track was reached at 480 seconds and the power applied again. A curve was reached at 560 seconds. At 595 seconds the current was again cut off and the train allowed to coast. At 615 seconds the brakes were applied and the train brought to rest.

The acceleration for the first 40 seconds was 0.25 miles per hour per second which is very good when the weight of the train is considered, as the locomotive weighs only 62.5 tons. Some changes were made in the apparatus on the locomotive before this test was made which accounts for the change in weight. During the steepest part of the acceleration curve the actual power taken from the line was comparatively low. The watt-hours per ton mile obtained (18.7) was remarkably low for such a high average speed and shows that not only was the train resistance low, but also that the efficiency of the locomotive was very high.

A much smaller amount of actual power was drawn from the line when the locomotive started as compared to that which would be necessary to start a direct-current locomotive under similar conditions. The controller used has on it nine notches, any one of which is an efficient running notch and thus gives a high efficiency for a large number of speeds. The different notches are obtained by bringing out taps from suitable points in the transformer winding. No starting resistance whatever is used. The line and motor volt curves became practically constant after the controller reached the "full on" position. The ampere and kw curves show a gradual decrease as the speed increased and the acceleration decreased.

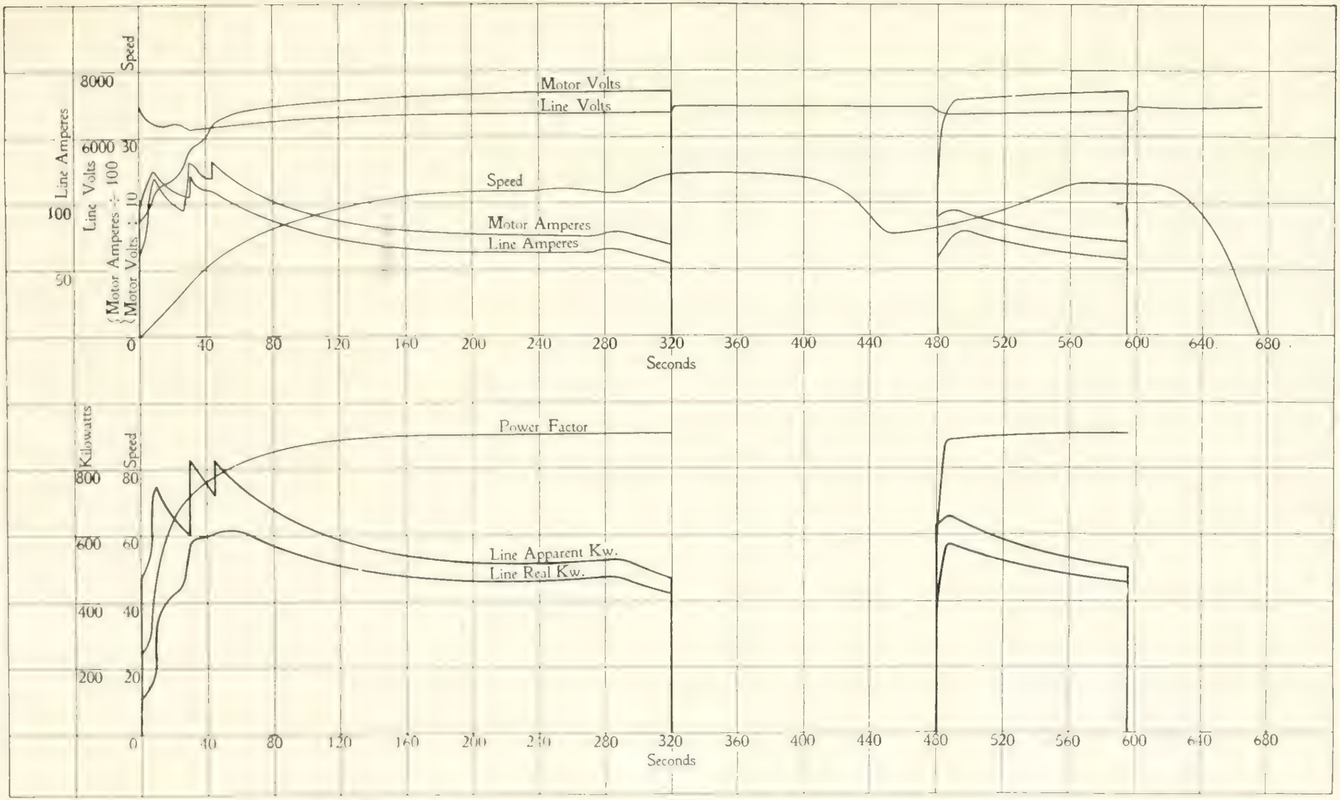


FIG. 4—CURVES SHOWING RESULTS OF TEST OF SINGLE PHASE LOCOMOTIVE

4–225 hp single-phase motors
Weight of cars, 818.3 tons
Weight of locomotive, 62.5 tons
Total weight, 880.8 tons

Gear ratio, 18:65
Length of run, 19,000 ft.
Time of run, 11 min. 15 sec.
Average speed, 19.2 miles per hr.
Average power, 85.5.

Diameter of wheels, 60 inches
Average line kw, 317
Kw—hrs. per train mile, 16.5
Watt—hrs. per ton mile, 18.7

EXPERIENCE ON THE ROAD

ITEMS OF EXPERIENCE IN ERECTION AND TROUBLE WORK

C. L. ABBOTT

MY instructions were not to interfere with the service and to keep the machines in operation at all times. As there was not enough time between midnight and five A.M. to move fifty tons of apparatus and make changes in foundations, it looked like a stiff proposition. There were four 250 kw rotary converters in two sub-stations, to be replaced by four of 300 kw capacity. When the situation was examined it was found that the sub-stations were so small that both old machines would have to be taken out of the building before either of the new ones could be installed, as there was not sufficient space for one machine to pass the other.

After spending a day figuring on plans that would not work, it was decided to put up a temporary sub-station close to the permanent one. An old tool shed belonging to a bridge contractor was rented, moved in sections, and set up on a floor of railroad ties that had previously been leveled and tamped with earth. A heavy wooden horse was then made, one of the 300 kw armature boxes rolled under it, and the armature lifted with borrowed chain blocks. Then the bed frame was rolled under and the armature lowered into its bearings, after which the top field was placed in a similar manner.

The rotary converter after being completed was rolled into the shed, connected to the switchboard by temporary wiring and run in parallel with one of the old machines, while the other one was taken out. The second 300 kw machine was then assembled and protected by canvas until midnight, when the remaining old machine was pulled out, the foundations changed, the new machine put in place and connected in parallel with the one in the shed. The second night the first machine was moved to its permanent foundations.

After this sub-station was completed the shed was again taken apart, hauled twelve miles, and a similar process repeated at another sub-station.

THE ELECTRICAL ENGINEER AS A BRIDGE EXPERT.

A little incident occurred in connection with this second sub-station work that indicates how a man sometimes has to assume responsibilities that he would rather delegate to others. It was necessary to haul a twelve ton piece on a three ton wagon over a bridge that was not of too recent construction. After the machine was loaded, the writer was notified by the "Selectmen" of the town that they would not be responsible for the bridge, and that they would hold him responsible for all damages. When the wagon arrived at the bridge about half the population of the town had gathered and were not only shaking their heads but had succeeded in shaking the confidence of the teamster, who wanted further instructions.

The only other way to the sub-station involved re-shipping the machine to the next town; and the stream was too swift to strengthen the bridge without much expense and loss of time.

After a careful inspection the decision was reached that the "Selectmen" were only "playing safe" and that there was little danger. The teamster was therefore told in reassuring tones, "That bridge will hold fifty tons. Go ahead." Although his best judgment told him that the bridge would hold, the writer confesses that while the wagon was crossing that creaking, rattling bridge, his heart beats were considerably above normal frequency.

EDITORIAL COMMENT

Single-Phase Locomotive Testing

The two articles by Mr. Bright which appear in the November and the present number of the JOURNAL give records of practical tests made on commercial single-phase railways for interurban service, as well as tests on the first large single-phase locomotive which has been built. Judging from the tendency of the times such tests will become very common in the near future. The present tests indicate that the power consumption of single-phase cars and locomotives is as susceptible of calculation as a corresponding direct-current equipment. Though the work is somewhat more complicated because of the greater number of factors introduced, it is none the less certain.

Three points which may be noted are, high average power-factor of the system, high tractive effort of the locomotive, and high efficiency.

Special attention is called to the high tractive effort obtained on the locomotive as this point has been questioned because of the pulsating character of the motor torque. The tractive effort secured in these tests is as high as could be obtained with a direct-current equipment.

The tests on this locomotive show further that the single-phase system is well adapted for slow-speed freight service; and as its adaptability to high-speed service is not questioned, the indications are that the single-phase system will cover the entire railway field.

N. W. STORER

Alternating-Current Problems

I have been interested in reading the introduction to a paper which I wrote nearly twelve years ago, a portion of which is reproduced in this issue of the JOURNAL. It speaks of the larger units and the higher potentials which were coming into service at that time. The largest alternators then in operation were about 1 000 hp, although contracts had been closed for the 5 000 hp units for the Niagara Falls Power Company. The highest voltages then in use in a few plants were 10 000 to 15 000 volts. At the present time an impetus similar to that which power service and the polyphase system gave to alternating-current problems a dozen years ago, is now being given by the single-phase operation of railways. The general problem of alternating-current transmission and distribution thus receives a new extension and is brought home to

railway engineers who may have had little to do with the characteristics of alternating currents.

There are some simple fundamental relations underlying various alternating-current phenomena which may seem at first complicated and perplexing. If one acquires a clear physical conception of the relations between the phases of currents and electromotive forces in an alternating-current circuit his problem is half solved. It is hoped that the elementary exposition of principles given in the article referred to will be helpful in giving definite concrete ideas regarding some common phenomena. CHAS. F. SCOTT

Single-Phase Railway Control

"The development of the switches and control apparatus is a more difficult matter than the development of the generators," was the remark of a man—now a well known engineer—eleven years ago when he was making tests on various switches and fuses which the current from the first Niagara generator promptly demolished. The design and arrangement of the various elements, which are collectively termed the switchboard, often receive far more consideration than does the generator.

In the new single-phase railway system great interest has been concentrated upon the motor. The type, the various features in the design, the general arrangement of windings, and the performance characteristics, have been the features which have awakened the most interest. The motor, however, is merely one of the elements and indeed the value of the motor lies not in the motor itself, but in the fact that it makes practicable the system as a whole. One of the important features in the single-phase system is the method of control. A most valuable feature of electric motors in general is their adaptability for running at different speeds, and a great deal of engineering thought and work has been devoted to the development of the control systems and apparatus for securing variable speeds, both from stationary and from railway motors.

In railway operation by direct current there are usually but two efficient speeds for the development of a given torque, namely, those secured by the series and the parallel connection of the motors. At other speeds rheostatic loss is involved. The desideratum is an efficient voltage control by which a high voltage may be applied for high speeds and a low voltage for low speeds.

In the single-phase system the alternating current may be transformed to different voltages either by the induction regulator

or by an ordinary transformer with a number of taps brought out from different points in the winding. The choice between the two methods is primarily one of simplicity and cost. Each has its advantages. The induction regulator secures a uniformly changing voltage. On the other hand, the transformer regulation involves simply a number of switching devices, is lighter and cheaper than the induction regulator and is under ordinary conditions more efficient. Mr. Jackson's diagrams of single-phase control in this issue of the JOURNAL show in detail the arrangement of apparatus for this latter method of control.

The voltage control materially increases the efficiency during acceleration as the rheostatic losses with direct current amount to a very considerable proportion of the total energy required during acceleration. The ability to select any one of several voltages enables a car or locomotive to be run efficiently at different speeds. If the trolley voltage be low it is impossible to prevent a low voltage on the motors in the direct-current system, but in the alternating-current system the ratio of transformation may be changed, giving the motors their normal voltage even if the line voltage be low.

CHAS. F. SCOTT

Useful Co-operation

Measured by their statistics, all departments of modern life—agricultural, mining, industrial, commercial, financial, social and moral, show a rate of activity and a wealth of accomplishment far in excess of that in past generations.

The striking feature of the present time is its accelerating rate of progress along so many lines.

These simultaneous developments are achieved by a common method. It is a new method, a new way of doing things.

This new universal method is co-operation.

The great discovery of the nineteenth century was the true value of CO-OPERATION, the effectiveness of concentration, the efficiency of largeness.

Mr. Kerr's paper in this issue of the JOURNAL therefore deals with principles which are fundamental. Some things which he says are particularly applicable to the men whom he addressed and the interests with which they are connected. Much that he says, however, is of much wider significance.

The modern method is co-operation. He shows how to make it effective.

CHAS. F. SCOTT

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OF

THE ELECTRIC JOURNAL

(VOL. I, No. 1, TO VOL. II, No. 6, THE ELECTRIC CLUB JOURNAL)

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TOPICAL INDEX

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The topical reference does not necessarily bear the author's original title of the article, but aims rather to give a good conception of the subject matter. The author's name and a short description follow; further characteristics are abbreviated by the letters T, C, D, etc.

T-Number of tables; C-Number of curves; D-Number of diagrams; I-Number of illustrations; W-Number of words.

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